In mid-nineteenth century California, entrepreneurs imported the blue gum eucalyptus from Australia, a fast-growing tree needing little water that could in a few years' time reforest treeless areas. The wood would be used for railroad ties, houses, and furniture.

However, as it turned out, the wood would often split or curve while being cut for logs. And it contained so many cracks that nails or spikes would not hold, making it unusable for homebuilding or rail ties. So the tall, fast-growing trees ended up as wind breaks in rural areas, but the fragrant leaves, nut-like seeds, and peeling bark created mounds of litter; even worse, during dry months the canopy often ignited, causing fires to sweep through elegant residential areas and threaten hillside homes.¹

Such unintended outcomes—sometimes called “revenge effects”—happen all the time. A miracle vaccine to prevent polio in children turned out to have been contaminated with a monkey virus that caused a lethal cancer. The vacuum cleaner and washing machine were intended to improve the standard of living of middle-class housewives. But as it turned out, these conveniences saved little time, because now women who previously
had hired housemaids and sent their dirty clothes to a commercial laundry felt obliged to clean their houses by themselves and do their wash at home.²

As long as there have been political and business elites, academics, planners, and ordinary reformers determined to solve societal problems, there have been, in Robert Merton’s phrase, "unanticipated consequences." Whether the unintended outcomes were the result of ignorance, error, vested interest, or some mix of these mattered little. Few of the problemsolvers who design the solutions are still around by the time their unanticipated consequences must be addressed.³

Even though Merton reminded his readers that unforeseen consequences are not necessarily undesirable, the examples usually cited to illustrate the phrase are mostly negative. But the things we don’t foresee are just as likely to be positive as negative. For example, when compulsory attendance laws required parents to enroll their children in public schools in the nineteenth century, coed schooling opened job opportunities for young women that previously had been closed.⁴

In answering the questions that guided this study, I found some outcomes that promoters intended, and some that were clearly unintended.

In the area of access to computers:

- **Expected finding:** Students and teachers had access to computers and related technologies available in both their homes and their schools.⁵
- **Unexpected finding:** Students and teachers showed little evidence of technophobia or resistance to using information technologies.

As for the way computers were used in schools:

- **Expected finding:** Those teachers who used computers at home, office, and school said that they communicated much more with colleagues, parents, and students than they had previously; they completed administrative tasks connected to teaching more efficiently (calculating student grades, writing notes to parents, compiling attendance reports, and so on); and they prepared for teaching with more depth and breadth in creating materials for student handouts and Internet searches.
- **Unexpected finding:** Less than 10 percent of teachers who used computers in their classrooms were serious users (defined as using computers in class at least once a week); between 20 and 30 percent were occasional to rare users (once a month); well over half of the teachers were nonusers.⁶
- **Unexpected finding:** In classrooms of serious and occasional users, most students’ use of computers was peripheral to their primary instructional tasks. Students used computers in schools to complete assignments, play games, explore CD-ROMS to find information, and conduct Internet searches. Only on rare occasions did student computer use become of primary importance, as in participating in on-line curriculum and creating multimedia projects.
- **Unexpected finding:** Less than 5 percent of high school students had intense "tech-heavy" experiences. These occurred mostly in nonacademic subjects or when students served as part of the school’s technical support system.
- **Unexpected finding:** Less than 5 percent of teachers integrated computer technology into their regular curricular and instructional routines.

These findings about access and use led to unexpected outcomes for teaching and learning:

- **Unexpected outcome:** In the schools we studied, we found no clear and substantial evidence of students increasing their academic achievement as a result of using information technologies.
• *Unexpected outcome*: The overwhelming majority of teachers employed the technology to sustain existing patterns of teaching, rather than to innovate.

• *Unexpected outcome*: Only a tiny percentage of high school and university teachers used the new technologies to accelerate student-centered and project-based teaching practices. (Most preschool and kindergarten teachers already used such practices.)

I am not arguing that teachers seldom change what they do in their classrooms. Teachers continually change their classroom practices. For example, some teachers quickly adopted computers for their classes, though most did not. Yet the teachers who decided to wait or chose to ignore the new technologies still engaged in changing other aspects of their teaching. Some may have decided to use a new textbook; others may have discovered a new way to do small-group work; and even others may have borrowed a technique from a colleague down the hall to press students to write more than a paragraph. These small changes are incremental and occur frequently among teachers. But these small adjustments are not what the promoters of computers had in mind. They wanted to transform teaching from the familiar teacher-centered approach to one that required the teacher to play a considerably different role. Using technology, the teacher would organize the classroom differently, giving students far more control over their learning (for example, working in teams on projects). Such changes would entail fundamental shifts in the teacher’s and students’ roles, the social organization of the classroom, and power relationships between teacher and students.

The point, then, is that teachers change all the time. It is the kind of change that needs to be specified. Champions of technology wanted *fundamental* change in classroom practice. The teachers that we interviewed and observed, however, engaged mostly in incremental changes. Only a tiny band of teachers moved toward deeper, major reform.7 These findings and outcomes will disappoint champions of better and faster technology in schools, especially those in Silicon Valley who have heavily promoted major investments in reforming schools through high technology.

**THREE QUESTIONS**

In the past when innovations aimed at changing classrooms have yielded disappointing results, reformers have often turned first to lapses in teachers’ knowledge and skills in explaining why the outcomes were unsatisfactory. Hence, I begin my explanation of these unexpected outcomes by asking three questions about teachers’ responses to technological innovations.

1. Are these *Silicon Valley* teachers’ responses to computers similar to or different from other teachers’ responses to earlier technological innovations? If these Silicon Valley teachers are similar to those from earlier generations of teachers across the country who faced technological innovations, then explanations for the unintended consequences would need to go beyond these particular teachers’ beliefs about technology to account for the similar patterns. If, however, teachers’ responses in the past to new technologies differ from these Silicon Valley teachers, then I would need to concentrate on Valley teachers’ individual characteristics, school conditions, and other features of the Valley itself to account for the differences.

2. Are these *Silicon Valley* teachers’ responses to computers
similar to or different from the responses of other professionals facing technological innovations? If teachers are similar to other professionals confronting new technologies, then, again, explanations for use and nonuse would have to go beyond Valley teachers' responses to computers and examine other factors. If, however, teachers reacted differently to new technologies, then a close examination of teaching as work would have to be undertaken.

3. In light of the answers to the previous questions, how do I explain these unanticipated consequences of new technologies in schools and classrooms at the turn of the twenty-first century? Faced with such evidence of apparent waste in resources, concerned citizens, policymakers, researchers, and practitioners naturally want to know why teachers aren't using the machines for instruction and why students aren't learning more, faster, and better.

As framed, these questions place the problem at the feet of teachers. Answers to these questions become explanations for teachers' classroom behavior when they are faced with technological innovations. Those explanations quickly get converted into solutions aimed at changing teachers' actions in their classrooms. So what I call explanations are really solutions-in-waiting to problems framed by those who invest in new technologies.

To sum up: these unexpected consequences arising from access and use of new technologies in schools attract policymakers' attention because the monies invested in technologies have yet to produce the desired outcomes. Policymakers partial to new technologies in schools view the unanticipated outcomes as problems. Problems need solutions. An explanation of why the problem occurs often contains the seeds of a solution. And this is why explanations are important to policymakers, practitioners, researchers, and informed citizens. Answers to these three questions frame the remainder of this chapter.

QUESTION 1

Are these teachers' responses to computers similar to or different from the ways that teachers responded to earlier technological innovations? In a previous study, I investigated teachers' responses to the introduction of the technological innovations of film (1910s–1940s), radio (1920s–1940s), and instructional television (1950s–1980s). Each of these highly touted electronic marvels went through a cycle of high expectations for reforming schools, rich promotional rhetoric, and new policies that encouraged broad availability of the machines, yet resulted in limited classroom use.

The cycle of attempted change invariably began with extravagant claims for the revolutionary power of films or instructional television to transform teaching and learning. Reformers, including public officials, vendors, foundation executives, and school administrators, fastened onto the new technology, promoting it as a solution for school problems. For example, in the 1950s promoters of instructional television hailed that new technology as a solution to a teacher shortage at that time.

As school boards and superintendents adopted policies and allocated dollars to secure new technology, few teachers were involved either in policy deliberations or in designing how new machines were to be distributed and used. Even without direct involvement, small bands of pioneering teachers begged for funds to acquire the school's first film projector, radio, or television monitor. These champions of technology influenced peers. Not too long after the projectors, radios, and monitors
appeared in schools, academic studies established that teachers using new technologies were just as effective, as measured by students' achievement test scores, as teachers using conventional practices.

But logistics gave teachers a headache. Securing a film from the district's audio-visual center at just the right time for a particular lesson or having the radio or television broadcast available at only one time and not other times caused problems. Incompatibility between the existing curriculum and the offerings of films, radio, and television further reduced use. These growing complaints from teachers about inaccessibility and incompatibility stained the mantle of acceptance that had begun to settle over the innovation.

Soon surveys documented teachers' infrequent and limited use of film, radio, and instructional television in the classroom. Based on these surveys, I estimated that since 1920 fewer than 5 percent of teachers used these technologies at least once a week. A larger number, perhaps 25 percent, were occasional users (at least once a month); the rest were nonusers. More precisely, teachers' and students' exposure to these technologies outside of school (which were already pervasive in this period) did not influence their use in classrooms.10

In classrooms where the new equipment was used, some teachers found that particular films or television programs motivated students to read the textbook, complete worksheets during the school day, and do assignments. Other teachers used the audio-visual equipment to give themselves a tiny break from the tough grind of constant interactions with students over a six-hour school day. In most cases, teachers used the new technology to maintain existing practices.11

Both administrators and teachers were criticized for failing to take advantage of powerful technologies that would, proponents claimed, greatly enhance both teaching and learning. Thus the cycle of high expectations, acquisition of new machines, and actual use of the technologies ended with disappointment and recriminations among reformers.

Much evidence over the last decade documents a similar cycle in the Silicon Valley schools' responses to information technologies. As before, public officials and school administrators rarely involved teachers in either the decisions to purchase and deploy computers or the designs for the technology's use in the school. Computers just suddenly appeared on teachers' desks and in special rooms set aside to house the machines, and then reformers watched in dismay as the machines sat idle.

One difference from earlier cycles of change, however, is that teacher are seldom directly blamed for this unexpected outcome. Instead, in the 1990s, public officials, corporate executives, vendors, and administrators call for better college preparation of teachers, improved technical support, and increased professional development to help teachers integrate software into daily instruction. Though the language is nonaccusatory, these calls for helping teachers are still, in Donald Norman's words, a "blame and train" strategy. By asking teachers to redouble their efforts, we take the spotlight off poorly designed hardware and software and inhospitable organizational structures that constrain teacher use.12

The answer, then, to the question of how earlier generations of teachers responded to film, radio, and instructional television is that they reacted much like Silicon Valley teachers did when faced with computers. A few "innovators" persuaded...
Oversold and Underused

“early adopters” to champion the new technology among their colleagues, followed by a very slow penetration into the majority of the teaching corps. Finally, even “laggards” joined the majority of teachers in using films and television; but uses in classrooms were infrequent, limited to maintaining customary practices, and peripheral to the daily routines of teaching and learning (save for a tiny fraction of teachers).13

From this glance backward at earlier generations of teachers, I can understand that their limited use of film, radio, and television equipment and programming had much to do with limited access. But Silicon Valley teachers in the 1990s have far more training and far greater access to information technologies, both at home and at work, than earlier generations of teachers were afforded. Today, the state of California requires new teachers to be computer literate, and the culture of Silicon Valley promotes and rewards technological changes that are intended to make teaching and learning faster and better. In such a place, I would expect a more intense use of computers in classrooms. The unexpected similarity in responses of past and present generations of teachers to the new technologies of their day presents a puzzle that I will return to later in the chapter.

QUESTION 2

Looking not backward, now, but sideways, I next ask: Are these teachers’ responses to computers similar to or different from those of other professions facing technological innovations? Engineers, military leaders, corporate managers, physicians, journalists, publishers, architects, and other professionals have followed the classic S curve in adopting new technologies: the enthusiasm of a few innovators is followed by early adopters, leading to gradual acceptance among mainstream professionals, and then a slow embrace by the last holdouts.14

Because there are few studies of how engineers, military officers, physicians, lawyers and other professionals conduct their daily work lives, it is hard to determine similarities or differences between teachers’ responses to information technologies and that of other professions. Moreover, it is difficult to generalize about an occupation. Engineers, for example, vary among themselves—mechanical, aeronautical, electrical, civil, and software engineers have different needs and adopt technologies in different ways. Added to that are major differences in institutional goals and structures: a small start-up software company’s response to technology is in many ways irrelevant to that of a large urban high school. Nonetheless, a brief inquiry into two occupations noted for their marked embrace of technological innovations and whose workplaces, routines, and incentives are vastly different from school teaching may offer clues to teachers’ responses to new technologies. The occupations are engineers and physicians.

Engineers

The little that social scientists know about how engineers go about their work comes from a few researchers who have studied product design, development, and manufacturing. A few case studies (including ethnographies) reveal much about daily routines in varied settings but seldom describe the technologies that engineers use or the actual work they do, except for a handful that examine particular technologies.15

What emerges from these studies of different kinds of engineering specialties is that the adoption of new technologies—whether it is a fully integrated robotized assembly cell that puts
together interior panels for commercial aircraft or a photovoltaic cell that improves a solar energy system—is a social, political, and organizational process. The social and organizational differences among engineers refer to the status differences between those in design (high), development (middle), and production (low) and the gap in status between professionals and production workers. Moreover, administrators and supervisors possess more authority than engineers—they often interrupt engineers in their work—and often choose what new technologies or software should be purchased and used by the engineers.

A manager at a large firm pointed out the traditional demarcations among engineering and construction in a southern California industrial company with departments using Computer-Aided Design (CAD). “Construction says ‘engineering doesn’t know what the hell they’re doing,’ and Engineering would say, ‘Construction are those overweight, stogie-smoking, get-down-to-the-brass-facts, don’t-follow-the-plans-if-I-don’t-have-to-kind of people.’ And engineers always felt—not always—but the typical attitude might be, ‘it doesn’t matter what I put on these drawings because Construction’s going to build it the way they wanna build it anyway.’

One senior design engineer working in a midsize company building industrial turbine engines described a portion of his work. “When you’re doing the mechanical design work, you have to be very aware of all the people that are interfacing and need to work with your design problems. You’ve got to leave room for the electrical people to put their stuff. You have to know how to put a package together so it can be built in the cheapest, most inexpensive way that you can possibly do. And to do that you are in contact a good portion of the time with other departments.”

Political negotiations continually color relations between managers and engineers in and among divisions and departments in a large firm. For some multilevel companies whose past successes have caused them to grow much larger and whose ability to respond quickly to market changes is reduced, entrepreneurial managers have developed a “skunk-works” strategy of innovation. The term comes from Lockheed Aircraft Corporation, which in the 1950s put together an elite group of the best talents in aviation, provided them with a mission and complete creative freedom, and equipped them with every tool they needed to accomplish the job. In short order, the Skunk Works, as this crack team was called, developed the U-2 jet aircraft, and it has continued to be a world leader in avionics innovation for over half a century. (The Skunk Works got its name from the “Skonk Works” of Al Capp’s Lil Abner comic strip, where a moonshine still was hidden in a secluded hollow.)

Tracy Kidder, in The Soul of the New Machines, described how the first 32-bit minicomputer at Data General was designed and built in the late 1970s using a skunk-works strategy. He portrayed engineers working on the secret project within the company as cheerleaders for technology who worked long hours in isolation while their project leader scrounged around for the resources they needed and buffered them from political battles within the company.

Being able to fathom what top corporate executives want and what will pay off for engineers and managers become essential survival skills. In one large successful aircraft company,
the divisional operations manager said: "Large or small expenditures in the division... had to meet the three informal rules that managers knew by heart guided corporate decision making; 'curb costs, increase productivity, and lose heads (i.e., reduce assembly workers)." 21

Within these large, midsize, and small companies, engineers used old and new technologies. Old technologies used by design engineers such as pen and paper to draw sketches and bench-built prototypes were as common as new technologies such as CAD-CAM (Computer-Aided Design and Computer-Aided Manufacturing) software. One researcher studied a large company whose top managers had purchased CAD-CAM. The new software builds a picture of a machine and provides the detailed pieces for design and manufacturing engineers to create, develop, and produce turbine engines. To help the conceptual design engineers learn the software, managers arranged two weeks of classes on a half-day basis: 4 hours of regular work and 4 hours of instruction each day. Training time was insufficient; experienced CAD operators outside the company had taken up to 6 months to learn the system's intricacies as applied to their products. Moreover, when designers did play with the system to learn it better, bugs in the software led to lost time and deep frustration with the new technology.

For experienced engineers, hand drawing remained more efficient, and they dropped the CAM part and used the CAD portion of the software in ways unanticipated by the vendor and company managers. As one engineer reported, "We design things on paper, and then hand it over to the CAD system. We use the CAD system as a record keeping, and rather expensive, fast eraser... We go backwards. Instead of building a picture and then taking the detail pieces off, we often end up going the other way around—which is wrong." 22 Company engineers facing a new technology that executives had chosen often ended up reinventing the tool to fit the existing organizational structures; as they did so, the relations among engineers and between departments also changed. Mutual adaptations occurred.

From design to production, engineers engage in a process that is social, political, and organizational. It is also fragmented, seldom linear, and filled with uncertainty. Such a process frustrates and goads engineers to adapt new and old technologies again and again in order to complete projects.

The conditions under which engineers work differ dramatically from those of schoolteachers in space, control over available time, supervision, and evaluation. Moreover engineers, unlike most teachers, use advanced and complex technologies constantly. Yet what emerges from these few studies of engineers are strong similarities to teachers. If design engineering in a company, for example, is a social, political, and organizational process, so is teaching. In schools, teachers in their self-contained classrooms are organized by grades or departments. They negotiate daily with students, colleagues, administrators, and occasionally parents. Like design engineering, which depends heavily on relationships between engineers and their managers and among engineers themselves in different parts of a company, teaching requires satisfactory relationships between students and teachers, among teachers themselves, and between teachers and administrators. If uncertainty is a hallmark of the journey in engineering from a drawing to a prototype to an actual product being shipped to customers, teaching surely has its daily surprises and unpredictable occurrences.
Finally, and perhaps most important for this analysis, like teachers, engineers selectively adopt, reinvent, and ignore new technologies to fit the workplace and the character of the work itself.

**Primary Care Physicians**

From what realms of knowledge do most primary care physicians and family practitioners draw to help their patients? Most draw on their clinical experience and knowledge of diseases to determine the value of diagnostic tests or the effectiveness of various treatments and to make predictions about patient's future health. The assumption is that prior training and common sense married to clinical experience are sufficient to allow a clinician to evaluate new diagnostic tests, treatments, and guidelines for practice. If physicians are stuck even after reflecting on their experience and biological knowledge of disease, they often turn to textbooks, recent journal articles, or local experts.  

Critics of medical practitioners point out that clinicians lean too heavily upon their idiosyncratic experiences and fail to consult in a systematic way the database of research studies available. First, without the benefit of a control group, it is impossible to tell whether a particular therapy was responsible for a patient's improvement or if the natural history of the disease would have brought about the same result without any intervention. Second, clinicians form impressions about what happened to former patients that permit them to estimate success but that hardly reflect actual rates of abated illnesses. Third, doctors, like most other professionals, want to believe that their diagnoses, therapies, and interactions help rather than harm patients. Thus unsystematic and anecdotal clinical knowledge is given higher priority than research-produced knowledge.

Beginning in the early 1980s, Evidence-Based Medicine (EBM) was designed to help practitioners tap the constantly expanding database of scientific studies and treat patients in a more systematic manner. As one of the innovation's advocates said: "Evidence-based medicine builds upon, rather than disparages or neglects, the evidence gained from good clinical skills and sound clinical experience." When doctors engage in systematic searches of the literature and incorporate findings into their daily work with patients, such work "keeps . . . clinicians up to date and effective."  

The innovation calls for family or general practitioners to access (via computer) the massive electronic database of research studies (MEDLINE, American College of Physicians Journal Club on CD-ROM, Cochrane Database of Systematic Reviews on CD-ROM, and so on) when treating patients with earaches, ingrown toenails, hypertension, and mysterious lumps in their abdomens. Once relevant studies have been electronically retrieved, especially those that include randomized clinical trials, the practitioner must critically appraise the studies to determine applicability to the particular patient. As the movement to persuade primary care physicians of EBM's value has spread, guidelines to help practitioners assess the worth of studies have been developed and disseminated through an increasing number of publications, professional development programs for practitioners, hospital resident programs, and medical schools.  

David Slawson recounted a story about his patient, a 43-year-old woman who had been admitted to an emergency room suffering from pneumonia. The emergency room doctor wanted to hospitalize her just to be safe. It occurred to Slawson to ask about the benefits to the patient of staying in a hospital. He told the doctor he would get right back to him. A family practitioner...
at the University of Virginia, he went to his desktop computer and entered data on the woman. With a few clicks of the mouse he found the “prognosis calculator.” Slawson determined that her odds of dying in the hospital would be 2.2 times higher (from exposure to germs and possible medical errors) than her odds of dying at home (from complications of the disease). He called the emergency room doctor and gave him the information that he had found. The doctor wrote a prescription and sent her home—saving her insurer, Slawson points out, thousands of dollars and, perhaps, hastening her recovery.27

What is missing from this best-case example is the pressured pace of daily encounters between family practitioners and their patients, and the continuing uncertainties that still mark the practice of medicine, either in solo or group practice or as part of a health maintenance organization (HMO). Primary care physicians who see 100 or more patients a week make upwards of 20,000–25,000 clinical decisions a year. As one British family practitioner put it: “I am already struggling with budget managers, contracts with secondary care [providers], and prescribing costs. I hardly have enough time to see all of my patients, let alone do the educational stuff I am supposed to do. And now you want me to look up a reference in some electronic library thing whenever someone comes in with an earache?” Another physician made the same point: “Busy clinicians are now caught in an information paradox: overwhelmed with information but unable to find the knowledge they need when they need it.”28

The few studies of family practitioners and other physicians using computers for access to relevant studies bear out the time pressure and the tensions facing doctors in finding the best treatment for their patient, reducing costs, and juggling the many other tasks expected of general practitioners. David Sackett, using studies of self-reported time that hospital-based physicians in the United States and Great Britain have to review journals, concluded that they have about 30 minutes a week for reading. Sackett believes that EBM can still occur, even within that small window of available time. He and his colleagues found that among British general practitioners, a range of 31 to 53 percent of the treatments they used fell into his definition of EBM. This is much higher than among U.S. non-hospital-based practitioners where, again, only a few studies have been done.

For example, Covell and his colleagues concluded in a study of doctors’ practices that of all the questions which arise when physicians examine patients, they pursued only about 30 percent of them. Curley and colleagues also found that the criteria practitioners used to determine whether they took the time to investigate other sources to answer questions arising from their patients were practical: which source of information was least costly to acquire, most accessible, and easiest to use?29

One study of U.S. rural and urban nonacademic practitioners (unusual in that it depended upon observations, interviews, and follow-up phone calls rather than self-reports) found that clinicians pursued 56 percent of the questions they judged most likely to have answers, compared with 13 percent of those least likely to have answers. These doctors used medical textbooks and clinical manuals (49.5 percent), consultants and colleagues (40.5 percent), and computer searches (2 percent).30

Although such limited use of computers to find information might have disappointed advocates of EBM, a 1998 study would give champions of the innovation even more discomfort. A survey was sent to almost 500 family practice residency programs in the United States to determine if they have electronic medi-
cal record systems. Most of the systems include information about patient demography, their files, assessments, and plans for care. Many also include an array of database searches that could be used for EBM. Because the Institute of Medicine of the National Academy of Sciences had recommended adoption of electronic records systems by the year 2000 and because residency programs are usually hospital and university based (with access to the latest information technology), one would reasonably expect such systems to be fairly widespread.31

The researchers found that 80 percent of the residency programs had never used an electronic medical record system. Only 17 percent of the programs currently use such a system, and 3 percent reported using a system but discontinuing it because of cost and unreliable software. Writing as advocates, the investigators still acknowledged that, in their own residency program, family practitioners argued that “dictating a chart note or writing prescriptions by hand is simpler, less time consuming, and as complete as the electronically captured document.” After analyzing the results, the authors concluded that computerized systems are “beset by the dilemmas of up-front and on-going costs, technological realities . . . [and] user resistance.”32

Admittedly, these studies are few. Nevertheless, what little evidence there is confirms that busy clinicians try hard to help their patients while both facing demands for cost-effective treatments and coping with the uncertainties of the progress and regress of disease. Nevertheless, these studies reveal practitioners choosing to adapt EBM, use it minimally, or ignore it.33

Summary of Answers to Two Questions

There is credible evidence, limited to be sure, that teachers’ use of computers in Silicon Valley, an area marked by strong support for innovation and technological progress, is similar to earlier generations of teachers facing new machines that also promised much improvement in teaching and learning. With less evidence but enough to make a plausible claim, I have also shown that engineers and physicians noted for their embrace of technological change (and who labor in workplaces quite different from that of teachers) have, like teachers, been very selective in their daily uses of technology, picking and choosing among those new ones that they can adapt most easily to traditional practices. Silicon Valley teachers’ use of new technologies, then, duplicates the history of the occupation’s response to earlier machines and shares patterns of use with practitioners in very different professions.34

These answers to my questions weaken the blame-filled explanations given for teachers’ limited and infrequent classroom use of technologies that promised to transform instruction. Explanations anchored in stereotypes of teachers as being more interested in interpersonal relations than in machines, or being by nature technophobic or reflexively opposed to change, fail to account for the vast majority of teachers who have become serious users of computers at home—outside the workplace. Nor do such explanations capture the enthusiasm for learning more about technology that teachers regularly express on surveys and interviews. Finally, these explanations ignore teachers who have become serious technology users at school, to the point of modifying common teaching practices.

QUESTION 3

In light of the answers to the previous questions, how do I explain the unanticipated consequences of new technologies in
schools and classrooms that have emerged so clearly in the early years of the twenty-first century? Explaining collective and individual teacher behaviors in using or not using technological innovations needs to go beyond popular explanations that tend to blame teachers for who they are and what they do. Alternative explanations consider personal choices and professional satisfactions interacting with the organizational, political, and social contexts in which people work.

Although the explanations that I offer below differ considerably from one another, they are not mutually exclusive. They overlap while retaining their distinct ways of accounting for the puzzling consequences arising from this study. I begin with the "slow revolution" explanation.

The Slow Revolution

This explanation says that small changes accumulating steadily will create a gradual transformation in how teachers teach. The 1980s and 1990s were only the initial stages of a long revolution that will eventually press teachers to increase the frequency, breadth, and integration of advanced information technologies into their classroom routines.

James Beniger takes the long view in The Control Revolution. He points out that there have been four "control revolutions"—that is, humans inventing new technologies to achieve control over their environment. The agricultural revolution almost 10,000 years ago, the commercial revolution a millennium ago, and the industrial revolution 200 years ago are three instances. The commercial revolution followed technical innovations in navigational equipment that permitted Europeans to explore Asia, Africa, and the New World. Governments subsidized colonization and commercial ventures and grew wealthy from the riches that flowed from their colonies. The control of information shifted from handshakes to commercial paper, from personal connections to large bureaucratic companies and government—all to achieve larger economic and social purposes.

The "computer revolution," according to Beniger, is only the most recent of a series of technological and economic changes by which information is collected, stored, processed, and communicated to achieve control. The economist Paul David takes a similar but foreshortened view in concentrating upon the past two centuries. He points out that during the Industrial Revolution in the United States, all of the technical developments for commercial applications of electricity occurred by the 1880s, but it was not until the 1920s that companies used dynamos to harness electric power to manufacturing, production, and distribution of products. There is, he argues, an inevitable lag between an invention and its commercial application.

Information technologies are in only the first half-century of their evolution and, like the dynamo, will trigger slow-motion changes in our institutions. Consider that the invention of airplanes in the early twentieth century rendered trains obsolete but not immediately. Passenger railroads did not begin to decline until after World War II. More than a half-century passed before travelers came to prefer air travel over train travel.

The slow-revolution explanation is easily applied to schools. Technological changes take far longer to implement in formal education than in businesses because schools are citizen-controlled and nonprofit. As systems, they are multipurpose, many-layered, labor-intensive, relationship-dependent, and profoundly conservative. Their primary mission is to make the next generation literate, prepare it for civic duties, and imbue it with the core values of the community. Determining when and
whether schools are successful in achieving these purposes is often contested; it depends on what graduates make of their lives and how much of that can be attributed to schools, how much to family upbringing, and how much to other factors that affect both teaching and learning.

Even with these differences between schools and businesses and the lag time between invention and widespread application, over the decades teachers have indeed changed their classroom practices. In the 1930s, for example, increasing numbers of elementary school teachers began using small-group instruction to teach reading. In the 1960s many teachers experimented with different ways of teaching math. Teachers have also slowly adopted technological innovations such as overhead projectors and videocassette recorders (VCRs). And as we have seen, in the 1980s and 1990s pioneering technology-users such as preschool teacher Esperanza Rodrigues, high school humanities teacher Alison Piro, and Professor of English Lawrence Friedlander have integrated information technologies into almost every aspect of their curriculum.

Over the years, then, many teachers have come to embrace some version of an innovation even to the point of teaching very differently from the ways they did before. The incremental process of adopting innovations to the point of reaching a critical mass of teachers, however, had often taken decades rather than a few months or years. Moreover, classroom implementation varied greatly from school to school and from teacher to teacher, because teacher beliefs, community expectations, and structures of age-graded schools, then and now, have been slow to change.  

Under a slow-revolution explanation, teachers’ adoption of personal computers for classroom preparation and communica-

tion, along with the evolution of “hard” and “soft” infrastructures, are early signs of deep changes to come. The evidence of limited use that I have offered, proponents of this explanation claim, merely reflects limited classroom access to new technologies. Once teachers have 4–6 machines and an array of software in their classrooms, a profound shift in teaching practices will occur. Changes will accumulate in upcoming decades much like other innovations—small-group teaching, reading and math innovations—in which teachers altered their core classroom practices. Within another half-century these changes in teachers’ beliefs, practices, and infrastructure will spread to most teachers. By then, technologies will have been thoroughly integrated into the daily classroom routine and, as promoters seek, teaching will have shifted from the prevailing teacher-centered to a student-centered practice.

The slow-revolution explanation is plausible. Its incremental view is clearly anchored in the belief that technological change in the larger society inexorably reshapes all institutions, including conservative ones such as schools. Today’s toddlers and children, who are quick with games and home computers, will press their parents and teachers unrelentingly toward greater home and school use of electronic teaching materials. If readers sense a technological determinism embedded in the explanation, they would be correct.

Still, this explanation has shortcomings. Why did the availability of new technologies in the 1990s lead most teachers to use computers at home far more than for instruction at school? Why, when teachers did become users, did most continue their customary teaching practices rather than adopt new ones? Nor does this explanation help us make sense of the sudden explosion in wiring, purchase of equipment, provision of technical
support, and infusion of professional development in the 1990s. Turning to an explanation that concentrates on contextual factors may help account for these shortcomings.

The Historical, Social, Organizational, and Political Contexts of Teaching

A second explanation for the unintended consequences emphasizes the societal role that schools perform in a democracy, the structures and work roles educators perform, and both the symbolic and actual nature of the technological innovation. These external contexts dynamically interact with internal ones to influence teaching practice. This explanation locates the gap between home and school uses of technology in the social and political organization of schooling, societal expectations for schools, and historical legacies, all of which influence what occurs in classrooms. Furthermore, this explanation tells us why teacher users of information technologies have continued rather than changed routine instructional practices. If the slow-revolution explanation emphasizes change over time, this explanation stresses the overall stability in teaching practices.

I begin with the striking emergence of a large, diverse ad hoc coalition seeking to replicate in public schools the technological transformation that had occurred in the corporate workplace. In the background, but of primary importance, was the state of the economy. The recession of 1991–1992, with an unemployment rate of almost 8 percent and an astonishingly high budget deficit, damaged the incumbency of George Bush and helped elect Bill Clinton as President. The easing of the recession ushered in the longest peacetime economic expansion of the twentieth century. By 2001, almost eight years of high employment, low inflation, and increased productivity—in part spurred by the explosion of technological innovations and further automation of the workplace—had turned the huge federal deficit piled up in the 1980s and early 1990s into federal and state surpluses. By the mid-1990s a growing economy was pumping money into public schools, an institution utterly dependent upon taxes from varied sources.41

But why schools? Beginning in the mid-1970s, critics, especially those from the private sector, connected America’s loss of global markets to Japan and Germany with the poor academic performance of American students and the unbusinesslike approach that educators took in schooling America’s children. The argument that economists and corporate leaders used again and again was that the United States would find it hard to outstrip Japan or other countries in productivity unless its schools produced literate and skilled graduates for the workforce. And that, they said, was exactly what schools were failing to do.42 Soon federal and state policymakers joined the chorus of criticism by setting national goals for public schools, raising academic standards, mandating tests to determine that the standards were being met, and holding principals, teachers, and students accountable by rewarding high test scores and punishing low ones, just as any efficiently run business would do. Dependent on sustaining the political legitimacy that public schools have had in the past, educators could do little more than protest details of the criticism and climb on board the popular movement to improve schools’ productivity. By the end of the twentieth century, standards-driven policies that called for states to test every student repeatedly, publish the scores, and hold teachers and administrators responsible for student’s academic performance had swept the nation. One tool to achieve that higher productivity, according to corporate and public officials, was the introduction of new technologies into the classroom.43
The American public has largely endorsed this business model for school improvement. By most measures, parents have expressed steady and increasingly strong support for computers both as learning tools in their own right and as critical preparation for a future workplace. In one 1995 public opinion poll, 75 percent of respondents agreed that “computers have improved the quality of education.” In another poll of voters two years later, 92 percent said that a school that is “well-equipped with computers” has a “very major advantage” over a poorly equipped school. In that same poll, voters believed that well-equipped schools had the advantage over less-endowed schools in “preparing students to enter the workforce” (92 percent), “making learning a more active experience” (86 percent), and “providing more individualizing attention” (70 percent).44

Public officials and corporate leaders experiencing an expanding economy increasingly driven by technological changes used the popular critique of schooling to justify large investments aimed at making schools high-tech institutions. Although it would be preferable to attribute expenditures for technologies to rational deliberations among public officials and corporate leaders, the broad support for new technologies in schools across all sectors of society suggests that more was involved than rational decision making. The reasons given for wiring schools and investing in equipment reveal less concern over whether the computer was effective in raising achievement or transforming learning and teaching than over the perceived imperative of simply getting machines into schools. Decisions to purchase hardware and software or wire schools were as much symbolic political gestures as they were attempts to actually acquire the right tool to get a job done well.45

By the late 1990s, the computer—like past mechanical marvels such as the steam engine, the railroad locomotive, and the airplane—had become, among other things, a high-status symbol of power and modernity. Within mainstream American culture in the decades preceding the twenty-first century, being “modern” meant being efficient, productive, businesslike, innovative, and forward-looking. Even the term “high tech”—like high fashion, high church, high class, high society—conveys an aura of superiority relative to other “low tech” methods and materials.46

For public school officials who rely on the good will and political support of voters, failure to redirect budgets toward building a technological infrastructure for teachers and students could be political suicide. Even with little evidence that investments in information technologies raise test scores or promote better teaching, most school managers use the rhetoric of technological progress to establish legitimacy with their patrons and the private sector. Similarly, university presidents, like public school boards and superintendents, are dependent on elites and various stakeholders for political and financial support. These institutions’ very legitimacy depends, in part, on demonstrating to donors, legislatures, alumni, parents, and voters that the universities are fulfilling their dual mission of creating and disseminating knowledge. Woe to the school leader unable to show patrons and visitors rooms full of machines. A “good” school has become, by definition, a technologically equipped one.47

HISTORICAL LEGACIES IN SCHOOL STRUCTURES, ROLES, AND ACTIVITIES

The university, like the American kindergarten and the comprehensive high school, is about a century old, although its ante-
cedents can be traced to the early decades of the nineteenth century. By the turn of the twentieth century, many antebellum colleges had dissolved their religious ties and embraced a secular mission committed to both teaching and research. In continuing to admit undergraduates, however, these emerging universities had to contend with the religiously based moral mission of the antebellum college that charged professors to build student character and cultivate citizenship—the teaching imperative. Facing this dilemma of reconciling research with teaching, presidents of these turn-of-the-century universities invented a compromise: the university-college.

Within this organizational structure, the mission of teaching and minding the moral life of undergraduates became embedded within discipline-based departments, the elective system, and required liberal arts courses called “general education.” Yet it soon became clear to new and veteran professors alike that any classroom innovations which expected changes in teaching practice would subtract valuable time from doing research. Thus, in accommodating new technologies into their daily work, it is unsurprising that most university faculties used computers much more for their research agendas rather than for teaching courses.

When school districts established high schools in the mid-nineteenth century, they chose as their model the small liberal arts college. District school boards approved curricula that prepared students for college, encouraged high school teachers to copy professors’ pedagogies, and endorsed organization into departments even to the point of recruiting teachers trained in separate academic disciplines. As the purposes of high school expanded to prepare students for industrial and commercial job markets, to build citizens, and to mold character, vocational departments, extracurricular activities, and student government were added. By the 1920s, the comprehensive high school as we know it today had emerged.

We can see these trends clearly in the case of Las Montañas High School. The local district school board and superintendent establish how large classes will be in each of the schools and allocate the appropriate funds. The superintendent monitors high school principals, who in turn oversee department heads working with individual teachers. The 1,300 students and 60 teachers at Las Montañas are divided into departments and have a daily schedule of six periods, each 55-minutes long. The structure of the six-period school day makes it difficult for teachers trained in separate disciplines to engage in school reforms, including integrating new technologies that ask them to cross subject-matter boundaries and team-teach with other faculty members. On two occasions, the Las Montañas faculty deliberated about changing the daily schedule to make it more flexible, and twice the teachers rejected a proposal to end the six-period day.

Other structures and external demands, often unseen and taken for granted, affect the way technology is used, or not used, in classrooms at Las Montañas. State and district requirements for graduation, age-graded organization, departmental boundaries, secondary teachers’ disciplinary training, and self-contained classrooms all combine to reduce cross-fertilization of ideas within and across departments and to encourage teachers to behave as academic specialists whose primary concern is covering the body of information contained within a textbook in 36 weeks. That most district and high school administrators decided to centralize school computers into labs and media cen-
ters rather than equip individual classrooms reflects, in part, available monies and, in part, the preferences of already harried academic teachers. Feeling that new technologies were an add-on to an already over-extended workday, those teachers wanted the autonomy to decide whether to take their classes to the media center or computer lab or stay put in their lower-tech classrooms. Yet despite the powerful legacies of the past in unforgiving contexts, a small but hardy band of Las Montañas teachers did nevertheless become serious computer users and made deep changes in how they taught.

History and context also matter for preschools and kindergartens. With the slow spread of private preschools throughout the twentieth century, an ideology and practice of early childhood education became embedded in the social organization of these schools. With its rug for circle time, toys, sometimes a small kitchen area, a wash basin, bathroom, cubbies for coats and cuddlies, and discrete learning centers located in various parts of the room, no one could mistake a kindergarten for a high school or university classroom. Parents came to expect a homelike setting with a caring teacher who was closer to a mom or dad than to a subject-matter specialist. They also expected the teachers to inculcate the virtues common to family and community life: being honest, respecting authority, helping others, sharing what you have, and cleaning up your own mess.

Educators' strong beliefs in how best to develop a young child's intellectual, social, physical, and emotional sides led to smaller classes in preschools and kindergartens than those in upper grades, playlike activities that cultivated each child's talents, and a teacher knowledgeable about children's stages of development and interests. The social organization of the classroom reflected these evolving beliefs. Each classroom had a teacher who expected each child to grow at his or her own pace through individual and group work and play, through activity centers and group tasks, while acquiring the skills and knowledge necessary for later school success. The teacher's role was to integrate various activities into a seamless web of lessons while walking the fine line between classroom order and individual freedom. The job also meant taking time to listen to each child's story, wipe away every tear, and share each small victory. If individual student choice and exploration, rather than mandatory activities and homework, ruled these settings, children still knew that the grown-ups were in charge.

Within this overall homelike atmosphere, computers have made few ripples. Adding a computer station to the existing learning centers—the water table, blocks, dress-up closet, climbing structure, book corner—expanded what children could choose to do and gave tangible evidence to both teachers and parents that the school had begun to help young children on the road to computer literacy. But no standard computer curriculum has evolved: the software that gets loaded on computers in a given school depends a great deal on what is available and on the school's academic or nonacademic orientation.

Contexts, past and contemporary, external and internal, shaped, in part, what occurred in early childhood programs, comprehensive high schools, and the university with respect to using computers for instruction. But there is another contextual factor that teachers themselves pointed out to us repeatedly: flaws in the technology itself. Since the nineteenth century, chalk and blackboard, pens, pencils, and textbooks have proven
themselves over and over again to be reliable and useful classroom technologies. Teachers added other innovations such as the overhead projector, the ditto machine (later the copying machine), and film projector (later the VCR) because they too proved reliable and useful. But most teachers continue to see the computer as an add-on rather than as a technology integral to their classroom content and instruction.

Policymakers and practitioners commonly see these old and new technologies as value-neutral devices, that is, as tools that can be used for good or ill. The evidence in schools, however, increasingly makes clear that wiring schools, purchasing computers, networking machines, and using the machines themselves are hardly value-free behaviors. Social practices accompany every technology, from electricity to the telephone, automobile, and airplane. Certain rules and procedures must be followed that slowly change the organizational, political, and cultural context of a classroom, not to mention a school.54 It is, in part, because of the potential of these new technologies to alter existing social practices of teaching and learning that teachers at all levels have expressed ambivalence about these powerful machines. Repeatedly, for example, administrators, coordinators, teachers, and students otherwise committed to using computers mentioned inadequate wiring, servers crashing, constant upgrading of obsolete software and machines, and insufficient technical support. Serious teacher users who were ardent pioneers of technology said that on any given day they had to have a back-up lesson plan, just in case the Internet search, on-line curriculum, Power-Point presentation, or word processing program disappeared because a server went down or was running too slowly. The unreliability and complexity of the technology undermined teacher confidence in its practical benefi ts. Even at schools with technology coordinators and rapid-response student assistants on-site, not all the troubles teachers experienced could be fixed immediately. On many occasions, teacher requests for help overwhelmed on-site support personnel.55

But a deeper analysis goes beyond the annoying breakdowns and basic unreliability. A few of the teachers and coordinators we talked with pointed to vendors who sell machines and software each year that are bigger, faster, and flashier but have little to do with what teachers want for their students. Donald Norman, former Hewlett-Packard executive and Vice President of Apple Computer, calls such company practices “rampant featurism.” He is unsparing in his criticism of the personal computer’s defects.56

“Do you think,” Norman says, that “311 commands is a lot for a word processing program?” Microsoft Word had that many commands in 1992. Five years later, the same program had 1,033 commands. Was the program easier to use, he asks? “Of course not.” Like the teachers, Norman knows that computer companies make their money by creating software that gets increasingly complex, requiring faster machines with more memory. When schools (and other organizations) can’t keep up with the costs of software, hardware, and wiring capacity, more crashes and glitches develop. The lesson Norman draws from rampant featurism is the importance of simplicity in design and use. The lesson I draw is that computers carry enough baggage with them to reshape the practice of schooling; they are hardly neutral tools.57

As consumers of technologies, teachers have no say about rampant featurism. Moreover, corporate marketing practices invariably produce incompatibilities between wiring, software re-
requirements, and machine demands. Seldom have teachers been asked what works best for them in various circumstances with different students. Because technology vendors sell to administrators, teachers often end up using machines that are far too complex for their classroom needs. For example, many of the software applications used in schools (such as spreadsheets and databases) were created for professionals in business. These applications required design features different from those teachers would need for teaching and learning. There is, as Ronald Abate says, a tool mismatch. The interaction between the new technologies, vendor claims, and the goals teachers strive to reach and the structures within which they work has created deep ambivalence among teachers, administrators, and students about what these machines and software can and cannot do.

As with the slow-revolution explanation, the history-and-contexts explanation is plausible. The past really does exist in the diverse goals of public schooling, present school structures, organizational roles, and decision-making processes. All of these affect what teachers in their classrooms do at various levels. What is missing, however, from each of these explanations is a straightforward answer to these two questions:

- Why did a small number of teachers become technological innovators?
- And why, among those early adopters, were there other teachers who then used computers to move from largely textbook-bound, teacher-centered practices to more intellectually demanding, complex forms of practice?

Because the prior explanations fail to account for these mavericks, I offer a final one.

As constrained as teachers are by the history and contexts in which they work, they still exert substantial discretionary authority in their classrooms. In age-graded schools with self-contained classrooms, teachers become gatekeepers for what content and skills are taught and how they are presented to their students, whether the students are 4 years old, 14, or 24. Although few teachers control class size and determine which students present themselves on the first day of school—district, state, and university administrators make those decisions—yet teachers do decide how the space, furniture, and time are to be used in their classroom. They decide how to group students and to what degree and under what circumstances students participate in class. They decide what instructional tools (texts, machines, and so on) best meet their goals for learning and what content in which order should be taught.

These are weighty decisions to make, and teachers' beliefs and attitudes about how students learn, what they should know, what forms of teaching are best, and the purposes of schooling all get factored into teacher decision making. Despite the constraints of context, teachers act independently within their classrooms.

In the case of information technologies, teachers make choices by asking practical questions that computer programmers, corporate executives, or educational policymakers seldom ask. And the reason is straightforward enough: schools serve many and conflicting purposes in a democratic society. Teachers at all levels have to manage groups in a classroom while creating individual personal relationships; they have to cover academic content while cultivating depth of understanding in
each student; they have to socialize students to abide by certain community values, while nurturing creative and independent thought. These complex classroom tasks, unlike anything software developers, policymakers and administrators have to face, require careful expenditure of a teacher's time and energy. So in trying to reconcile conflicting goals within an age-graded high school or a bottom-heavy, research-driven university, teachers ask themselves down-to-earth questions in order to decide which electronic tools they will take to hand. Here are some of the questions teachers ask:

- Is the machine or software program simple enough for me to learn quickly?
- Is it versatile, that is, can it be used in more than one situation?
- Will the program motivate my students?
- Does the program contain skills that are connected to what I am expected to teach?
- Are the machine and software reliable?
- If the system breaks down, is there someone else who will fix it?
- Will the amount of time I have to invest in learning to use the system yield a comparable return in student learning?
- Will student use of computers weaken my classroom authority?

Drawn from the everyday experiences of teachers in preschools through graduate schools, these practical questions have a gritty merit to them that few vendors or educational policymakers distant from classrooms and unmindful of the varied social purposes that tax-supported schools serve could ask. Nevertheless, I suspect that other professionals, including engineers and physicians, ask similar practical questions of new technologies every day.

The situational autonomy that both novice and experienced teachers have in classrooms means that choices are made daily. The beliefs and values that teachers hold drive many of the choices they make in the classroom. The satisfaction they gain from student learning and the interpersonal relations that grow daily are high on most teachers' lists. In a 1996 national poll, for example, 76 percent of teachers said that it is essential for students to display "curiosity and a love of learning." When that curiosity and learning occur, teachers glow.

Teachers, and those who write about teaching, often talk about the "joys of teaching," "the teachable moment," and the occasional prickly sensation on the back of one's neck when an antagonistic student accepts the help of a teacher or when a group of students volunteer to work after school on a project. Between teachers and students, emotional and intellectual exchanges occur. Trust and affection evolve into life-long, cross-generational friendships. These relationships are deeply satisfying to teachers. They are, in Dan Lortie's words, the psychic rewards of teaching.

Earning those psychic rewards depends a great deal on the contexts that teachers interact with and the range of beliefs and attitudes they have about teaching and learning. These contexts, beliefs, and attitudes vary considerably. Some teachers want to teach in just the way their favorite elementary or high school teacher did. Others are motivated by a desire to be just the opposite of their worst teacher. Many teachers believe in high academic standards, demanding homework, whole-group discussion, and lecturing. Many teachers believe that the way to engage students is with small-group work, structured choices, individual projects, and hands-on activities. And many teachers construct hybrids of these differing beliefs.

Although a teacher's mindset may not steer all of his or her
classroom actions—because of organizational and other contextual factors—they clearly influence how the classroom is organized for instruction and how teaching is approached. Beliefs influence where teachers decide to teach, what and how they choose to teach, the satisfaction they achieve in their classrooms, and the degree of dissonance, even conflict, they feel and express when their values are compromised.

The maverick computer-using teachers I have identified—Alison Piro, Esperanza Rodrigues, Mark Hunter, and Lawrence Friedlander—sought to substantially change their instructional practices. They welcomed computers with open arms, took courses on their own, incessantly asked questions of experts, and acquired the earliest computers available at their school or for home use. They did so because they sensed that these machines fit their pedagogical beliefs about student learning and would add to the psychic rewards of teaching. Most of the innovators used computers to support existing ways of teaching. Others not only embraced the new technology but also saw the machines as tools for advancing their student-centered agenda in transforming their classrooms into places where students could actively learn.

Thus, even within the constrained contexts in which teachers found themselves, teachers—as gatekeepers to their classrooms—acted on their beliefs in choosing what innovations to endorse, reject, and modify.

SUMMING UP

The introduction of computers into classrooms in Silicon Valley schools had a number of unexpected consequences. They are:

- Abundant availability of a “hard” infrastructure (wiring, machines, software) and a growing “soft” infrastructure (technical support, professional development) in schools in the late 1990s has not led, as expected, to frequent or extensive teacher use of technologies for tradition-altering classroom instruction.
- Students and teachers use computers and other technologies more at home than at school.
- When a small percentage of computer-using teachers do become serious or occasional users, they—contrary to expectations—largely maintain existing classroom practices rather than alter customary practices.

Explanations that indirectly or directly blame teachers collectively for infrequent use of new technologies and sustaining existing practices even when there were machines available are inadequate. In examining how earlier generations of teachers responded to new electronic technologies and exploring how engineers and family practitioners adapted to new technologies, I concluded that there were similar patterns in responses to new technologies from teachers then and now and from practitioners in very different professions.

The three explanations I offered (slow revolution, history-and-context, and contextually constrained choice) easily meet the test of plausibility. But a plausible explanation is neither necessarily credible nor persuasive. Because explanations contain the seeds of policies (that is, each explanation offers a solution to a policy problem), it is important to close the gap between plausibility and credibility.

The slow-revolution explanation is appealing, especially for those who believe in the inevitability of technological progress. Simply put, more and more teachers will become serious users
of computers in their classrooms as the "hard" and "soft" infrastructures mature in schools. This explanation also suggests that uses of technology to preserve existing practices will continue among most teachers but give way slowly to larger numbers, especially as high schools and universities shift to more student-oriented teaching practices.

For the tiny band of teacher-users who have already transformed their classrooms into student-centered, active learning places, the slow-revolution explanation places them in the vanguard of a movement that will eventually convert all classrooms into technology-rich sites. Embedded in the explanation is a supreme confidence that with further work to secure better equipment, more training, and adequate technical support, as the years pass a critical mass of users will accrue, and the gravitational force of this group will draw most of the remaining teachers into technology's orbit.

Although the slow revolution can be persuasive in taking the long view to explain some of the unintended consequences we found in our study, this explanation is silent about the surge of spending on technology in schools in the 1990s and not a decade earlier or later. Nor does this explanation account fully for both teachers' and students' broader (and more frequent) use of technologies at home and office than at school. Both young and old seemed to have learned quickly to use the new technologies at home. Why not at school? It is a question not easily turned aside by the comment that this discrepancy, too, will disappear in time.

The history-and-contexts explanation suggests more complex, deeply embedded factors that will continue to retard widespread classroom use of technology. For example, the web of traditional social beliefs held by taxpayers, parents, and public officials about teaching and learning, and the broader historic purposes schools serve in a democracy have a powerful influence on what educators think and do. Also consider how economic prosperity and recession expand and reduce the revenues flowing into the public schools, ultimately influencing what is available for spending on new technologies and technical support, reducing class size, building more preschools, broadening professional development, and designing innovative programs.

In the high schools we observed, two outcomes become understandable through the history-and-contexts explanation: teachers' higher use of computers at home than in classrooms, and (among those who use computers for instruction) a tendency to adapt technology to support existing teaching practices rather than alter them. Consider the historical constraints imposed on high school teachers—even the most techno-enthusiastic among them: the separate classrooms, individual departments, age-graded groupings, and six-period work day. Add the time spent by each teacher to work out the logistics necessary to bring classes to media centers and computer labs. Then factor in nervousness over possible server crashes, software foul-ups, printer glitches, and slow Internet connections. Any high school teacher who manages to use computers in the classroom has somehow overcome a host of organizational obstacles, political decisions made by others remote from the classroom, and difficulties associated with the technology itself, including mismatches between "rampant featurism" and the teacher's practical needs in the classroom.

In preschools and kindergarten, the historical residue of early childhood ideology, classroom organization, and teacher practices nicely accommodated one or two classroom comput-
ers within the familiar schedule that has children going to various activity centers for part of the day. Although some teachers may have had reservations about young children using computers, for the most part those reservations dissolved in the limited contact that 4- and 5-year-olds had with computers. Most early childhood teachers already were committed to active learning, direct experience, and projects. They already structured their classroom space and activities to encompass the children's intellectual, social, and emotional development. In effect, they maintained their existing student-centered practices while using computers.

Within the university, the invention of the university-college, bottom-heavy decentralization, and structural incentives and rewards drove most professors to value research more than teaching. These facts of university life constrained most professors from investing the time required to use computers for teaching but not from embracing them for use in their research, in preparing for lectures, and in communicating with colleagues and students. Except for a small group of professors, then, most would continue to teach as they had before the introduction of computers. Moreover, the administrators and technologists who designed strategies to introduce new machines involved few, if any, professors in their decisions to purchase and deploy computers.

The interplay between historical, organizational, economic, social, political, and technological contexts has much explanatory power. What occurred in these varied settings was a mutual adaptation between workplace demands on teachers, what they found useful in the technologies, and the institutional arrangements. Yet both the slow-revolution and the history-and-context explanations fail to account for the small cadre of teachers who went against the mainstream to become serious users of computers at home and school. Nor do these explanations account for a few mavericks who embraced the new technologies to create classrooms where students inquired more deeply into subjects, crossed disciplinary boundaries, and experienced learning in ways they had seldom encountered in schools. It is the explanation of teachers making contextually constrained choices that highlights why small bands of teachers acting autonomously used computers to transform their classrooms.

Although I am tempted to combine the different explanations into one that covers all of the unanticipated outcomes I have identified, I resist that lure. Yes, the slow revolution is compelling simply because any parent, researcher, or policymaker who has gone into schools repeatedly over the last decade can see the obvious increase in computers. Yet the ardent promoters' chain of logic that access will lead to widespread use and use will transform teaching and learning has yet to be realized in Silicon Valley schools. I find compelling the combined explanations of historical legacies and the contextually constrained choice of teachers in accounting for the patterns of teacher and student use in different levels of schooling. The two explanations, taken together, persuade me. Even if every single child had a personal computer at home and in school in the next decade or half-century as a consequence of the slow revolution, I believe that core teaching and learning practices—shaped by internal and external contexts—would remain very familiar to those who would visit mid-twenty-first-century schools.

In the final chapter I elaborate my position by examining advocates' claims for reforming schools through technology and the implicit policies buried in the three explanations and answer the question: Are computers in schools worth the investment?