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Technology Management in Secondary Education

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Executive Summary

This paper stems from an initiative of the Decision Education Foundation, a nonprofit organization that teaches decision-making skills to high school students. Through DEF I led a project with six others (Jack Kloeber, Jen Nebbia, Paul Schoemaker, Dave Smith, Louis Thomas, and Keith Weigelt), along with Dave Reiter, DEF Managing Director, to create and teach a Decision Sciences curriculum to a group of students at Mastery Charter High (at the time called High Tech High), a charter high school in Philadelphia, Pennsylvania.

Although DEF volunteers taught this pilot course, our goal is to have teachers themselves teaching the material. Since this decision analytic course involved some probability and mathematical weighting, we had hoped to find appropriate computer-based materials for teachers. This would make it easier for teachers to quickly become familiar with this new material. It would also be useful in analyzing student work, while introducing motivational factors for the students themselves. However, I found that there is little abstract computer-based instructional material. This discovery caused me to take a step back and try to better understand computer usage in America's classrooms, especially.

I found a near-unanimous acceptance of the idea that computers *should* be in the classroom. Adults are used to working with computers in their everyday lives. The government actively sponsors programs to bring computers into schools, and some corporations have partnered with school districts and are providing money and expertise. But although computers may belong in the classroom, there has been very little cost-benefit analysis conducted and very few reliable educational outcome measurements.

Educational software availability seriously lags behind hardware availability. The hardware infrastructure is in place. But the education software is still at DOS level 2.2. It is the education software that contains both promise and pitfalls. Scott Gordon, CEO of Mastery Charter High, is on the frontline of computer-assisted education. His advice to schools: start off slow and cheap.

For successful implementation, schools must overcome two dangerous pitfalls. 1. Sticking with the Familiar. Schools are applying old teaching methods to this new technology. Instead, they must work with software companies to determine the best way to learn on computers. 2. Failure to fully commit. Schools are not fully committed and treat this new application as any other application. However, computer-aided technology integration is much more complicated. It requires identifying and working closely with all stakeholders.

Schools must create appropriate incentive structures for stakeholders. For instance, teachers need technical training and support, and recognition for this time commitment. Software developers need financial rewards – perhaps by many schools adopting the same software, or by developing in students a brand loyalty to a particular software house.

My thanks to Paul Schoemaker, Professor of Wharton School of Business, for his guidance with this paper and the opportunity to incorporate his knowledge of emerging technologies in education. Thanks also to Keith Weigelt, Professor of Wharton School of Business, for his advice on this paper; Scott Gordon, CEO, and William Walker, IT Manager, at Mastery Charter High, for their insights on technology management in education; Dave Reiter, Managing Director of Decision Education Foundation; DEF volunteers Jack Kloeber, Jen Nebbia, Paul Schoemaker, Dave Smith, Louis Thomas, and Keith Weigelt; Richard Andrews, math teacher at Mastery Charter High; Laura Keane, curriculum developer, and Deborah Stern, Director of Education, at Mastery Charter High.

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Abstract

As seen in the recent "No child left behind"[1] educational policy initiative, America has invested considerable money to give all students access to computers and enable them to be competent citizens of the Information Age. This explosion of technology in secondary education in the United States raises a number of questions that will be addressed in this paper:

1. What role is technology playing in our schools today?
2. How is technology improving student education?
3. Will the education gap by wealth increase due to technology?
4. What are the implications for managers of technology in secondary education?
5. How should managers of secondary education prepare for technology's future?

There are generally five types of computer uses in education: individual learning, group learning, instructional management, communication, and administration. This paper focuses on the needs of students in particular, in both individual and group learning environments, and student-related communication. More specifically, this paper focuses on computer-aided instruction, or instruction that "uses computers to teach things that may or may not have any relation to technology."[2] Computer-aided instruction should be clearly differentiated from computer-skills training, which "teaches students about computers." (However, students often develop their computer skills through computer-aided instruction.) Additional benefits of technology that support education but do not directly involve instruction, such as administrative assistance for teachers or ancillary improvements in the Internet navigation and word processing skills for students, are not

[1] US Department of Education, 2002
[2] President's Committee of Advisors on Science and Technology, 1997

included in this discussion. While the latter certainly support education, they do not involve actual instruction.

The explosion in technology has not yet paid the anticipated dividends. This is in part because teachers don't feel prepared, the appropriate software isn't available or is difficult to find, and the appropriate school support isn't yet in place.

Nevertheless, having technology in the classroom has motivated students both by making learning more fun and because students themselves realize technology will be important to their future careers, and as a result are eager to learn.

Technology has decreased the educational gap rather than increased it. Having access to the Internet has improved educational opportunities for rural, poor and homebound students by making learning more accessible.

Additionally, government funding has helped to ensure that underprivileged youth have access to many of the same technologies available to students in wealthier schools. However, though the hardware is available, the teacher training and IT support is weaker, and the software applications used are not as sophisticated – and this could indeed widen the educational gap in the future.

This paper recommends that schools start off simply. Schools can turn to used and donated computers, and can begin with pilot programs before rolling out technology across the school. Schools must also focus on IT support, curriculum reviews, and teacher training, if computer-aided instruction is to succeed.

Schools should also help create the future scenario they desire. One idea: Schools could partner with other schools to create a board that finds valuable software, and develops best practices. This board could also partner with software companies to develop the best solution, and perhaps even policy makers to help make it affordable.

What role is technology playing in our schools today?

Many of the questions raised about computers in the classroom 20 years ago are still being posed today. A 1985 report posed 4 questions: "What is the appropriate place for computers as an object of instruction in today's curriculum? Can the intellectual accomplishments of adolescent students in English, social studies, sciences, and other subjects be substantially improved by their use of computer-based tools? For which types of students, and for what portion of the traditional curriculum, are computers a cost-effective way of improving student skills and competences? How can computers be efficiently used in school settings, where teachers are responsible for supervising the activities of 25 or more students, but where computer screens and keyboards are typically used by individuals or pairs of students?"[3]

More succinctly: How can computers teach? How can what they teach be measured? How do they integrate with teachers? Variations of these questions are still being asked today.

Hardware and infrastructure

The Clinton Administration, in its Technology Literacy Challenge, articulated that our education technology objectives must build on "Four Pillars:" hardware, connectivity,

[3] Becker, 1985

digital content, and professional development; and, all in that order. From 1991 to 2001 the US government spent over $ 40 billion on education technology[4].

Although most educational technology funding comes from the government, other sources include school donations and corporate gifts. General estimates on funding sources are: [5]

State education departments and other state agencies:	25%
Local:	40%
Federal:	30%
School Fundraisers:	2%
Corporate Gifts:	3%

According to the National Center for Education Statistics, from 1994 to 2001 the percent of public classrooms connected to the Internet increased from 3 to 87 percent.[6] In raw numbers, the US school systems are already ahead of other countries. In 1995, US secondary schools had one computer for every 12.5 students, a ratio topped by only two other countries worldwide – the UK at 8.5 students per computer, and Canada at 10.0 computers per student.[7] By 2001, the US computer-to-student ratio was as low as 5.4, and 10 percent of public schools lent laptop computers to students. By 2002, the student-to-computer ratio reached 3.8 to 1.[8]

[4] CEO Forum on Education and Technology, 2001
[5] State-of-the-States Survey, 2002
[6] CEO Forum on Education and Technology, 2001
[7] The McKinsey Quarterly, 1997
[8] Staresina, 2003

Use of technology in the classroom

Email and Internet use have become common components of education. Sixteen percent of schools reported that email addresses were available for students in 2001.[9] Seventy five percent of public schools had a web site in 2001. Among these schools, 57% reported that students contributed materials to the web site and participated in its creation, and 31% reported that students participated in web site maintenance.

A national survey among students with a home computer (68.6%) found the following activities to be most broadly engaged in: [10]

Games	83.3%
Internet	74.6%
School work	73.9%
Email	61.0%
Word processing	56.6%
Graphics and design	~0%
Spreadsheets	~0%

How is technology improving student education?

Few educational innovations have grown to command such large budgetary expenditures in such a short span of time as have computers. But what has been the return on this investment? To answer this question and create a vision for technology in the classroom, the CEO Forum was established. The forum is comprised of members such as Apple, Hewlett Packard, IMB, Compaq, Sun, NetSchools, Dell, and others. The CEO Forum cites two laudable goals of education technology: 1. Improve student achievement. 2. Develop "21st Century skills." "Educational technology" (used here to mean computer-assisted learning) has the ability to integrate digital content and

[9] National Center for Education and Statistics, 2001
[10] National Center for Education and Statistics, 2001

connectivity into the curriculum with software and computer simulations, CD-ROMS, the World Wide Web, real-time video discussions, and databases. Educational technology, the forum feels, should be able to improve student achievement because it is interactive and engaging, manipulative, instantaneous, and creative. It helps students use information in a collaborative fashion as they explore subjects in greater depth and complexity than otherwise possible. Additionally, the forum believes that due to its various formats, digital learning allows students the flexibility to learn in their preferred manner, be that visually, audibly, or analytically.

But how does this work? According to Nevens, a strong proponent of educational technology, "As technology spreads through the schools, teachers and students will assume new roles. Students will pursue more self-directed projects and set their own goals; teachers will take on the role of facilitator. Parents and outside experts will form part of each student's learning team."[11]

Such goals are ambitious but reminiscent of previous expectations of technology revolutionizing the classroom that ultimately failed to materialize. As Angrist stated, "Politicians, educators, parents and researchers have long looked at technology to improve schools. One of the earliest advocates for technology in the classroom was Thomas Edison, who predicted in 1922 that motion pictures would revolutionize education and 'be an epic in the common school.' Edison himself funded educational films, though he also complained about lack of teacher interest and high production cost. In the 1950s psychologist B. F. Skinner published a series of papers predicting that

[11] Nevens, 2001

'teaching machines' would make learning dramatically more efficient."[12] Expectations continue to surpass results.

Thus, we cannot escape the research necessary to understand how technology has improved our classrooms thus far.

Quantitative case studies

Although the US government has set the integration of technology into education as a high priority, few studies have been conducted to understand the effects. As Angrist notes, "Perhaps the most important shortcoming in the case for further investment in CAI (Computer-Aided Instruction) infrastructure is the fact that the evidence for effectiveness is both limited and mixed. Although CAI has been around for decades, there are few empirical studies that meet a rigorous methodological standard. Many studies are qualitative, gathering impressions from participants in demonstration projects, or quantitative but with no real comparison group. The results of those studies that do not attempt to compare outcomes between CAI-trained pupils and other pupils are hard to assess." [13]

Below is a look at the few quantitative studies extant.

Case study: Union City High

From 1992 to 1997 Union City School underwent a major technological makeover known as Project Explore, greatly aided by Bell Atlantic. The Center for Children and Education studied the effects of this technology-infused education. [14] Union City is an urban school where 28% of students live below the poverty line and 79%

[12] Angrist, et al, 1999
[13] Angrist, et al, 1999
[14] Chang, et al, 1998

receive free or reduced-price lunches at school. Ninety-two percent of students are Latino, of whom 75% do not speak English at home.

The Project Explore initiative increased the student-to-computer ratio to 4:1. Students in the Explore program had access to word processing, spreadsheet and database programs, and Internet resources (including email) both at home and at school. The non-Explore group had more limited technology resources and Internet access and did not have email.

The technological effort was part of a larger effort – a five-year Correction Action Plan from 1992 to 1997 that included changes to class structure, greater in-service training of teachers, refurbished buildings, curriculum reforms, and a budget increase that tripled – from $37.8 million in 1989 to $100 million in 1997. Thus, many additional factors were at work for Explore students: Enthusiastic and dedicated staff selected from teachers district-wide, high expectations placed on students, greater involvement of parents through the district's efforts of increased communication and computer network connections among students, teachers, and parents.

As one teacher said, "Parents, through our program, have become aware of the technology resources that students have at school for accessing and presenting information. As a result, they are making more demands on their children, mindful of the wealth of facilitating materials that are at their disposal." There were also a number of events planned to create an atmosphere of success for Explore students, including a kickoff and public relations event that included Bell Atlantic, and local, state and federal politicians. The US Department of Education cited Project Explore as a milestone in education history. Visitors, including members of the press, educators, business leaders, and state and national policy makers followed both events. Students and faculty spoke about their experiences to audiences all over the world in videoconferences.

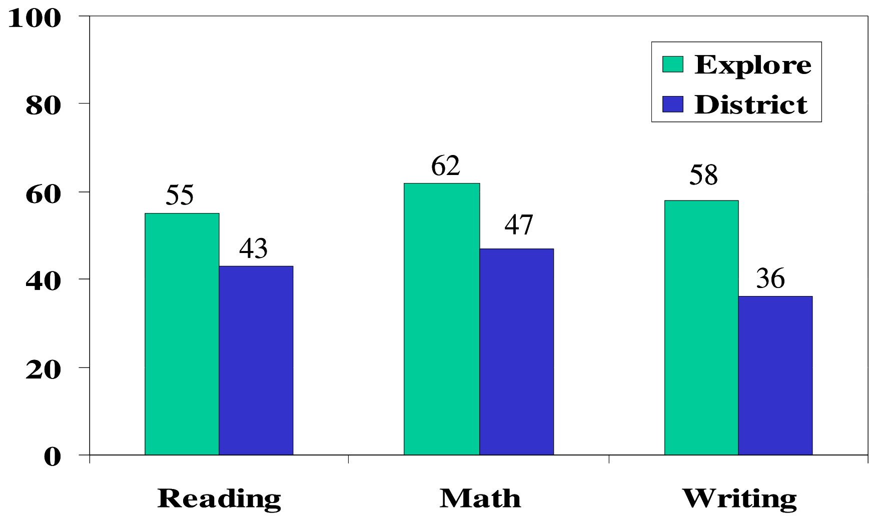
In 1996, President Clinton announced a new multi-billion-dollar initiative (America's Education Technology Challenge) while at Union City, citing Union City as a model for the country: "This school system is undergoing a remarkable transformation. I want the rest of the country to know about it, and I want everybody in the country to be able to emulate it."

To study the impact of this technology infusion, Union City compared students in the Project Explore group to other students in the district on the basis of the percentage of students passing the Early Warning Test (EWT), a high school proficiency test that scores students from 0 to 100. The study results looked impressive. By the ninth grade (1996, three years into the study), there is a statistically significant difference in the percentage of students passing the EWT, as shown in Figure 1.

Figure 1

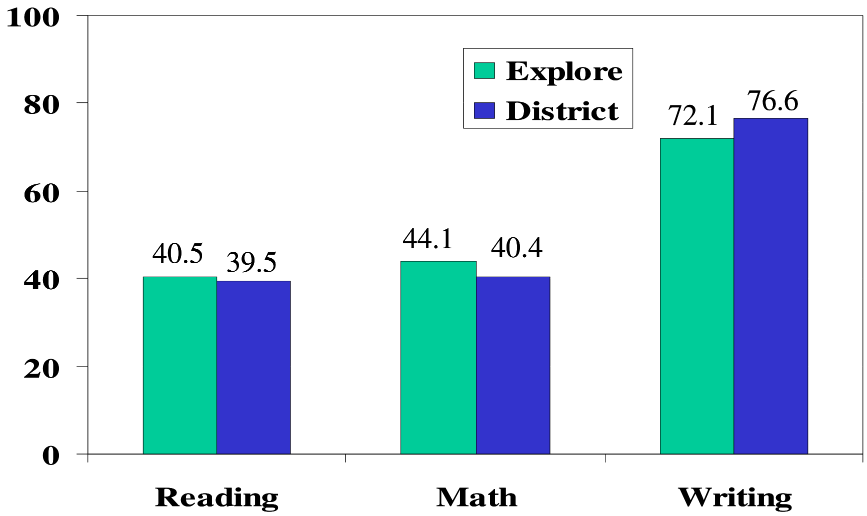
Students passing the 9th Grade EWT exam.

Percent



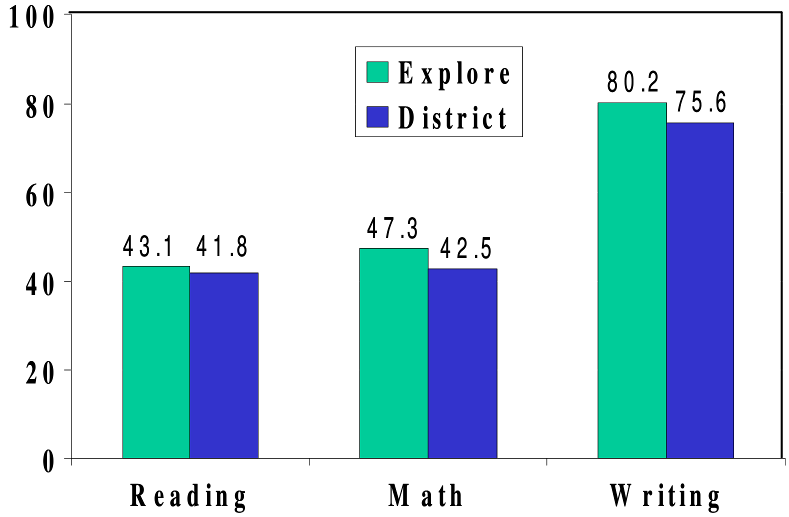
These dramatic findings prompted the Center for Children and Technology to take a closer look at the data. It found that students in both groups are not directly comparable, as they differ by gender, English language proficiency, and ethnicity. The CCT created its own controlled analysis. It changed the study metric to be standardized test scores on the EWT rather than simply passing the test. The results for ninth grade are shown in Figure 2.

Figure 2: Ninth grade (1996) EWT Mean Scores



The mean scores are similar, and the writing scores are actually better in the district group. However, if only comparing those 9th grade students in the group who have been in the program the longest (since 7th grade), the results are more as expected, as shown in Figure 3.

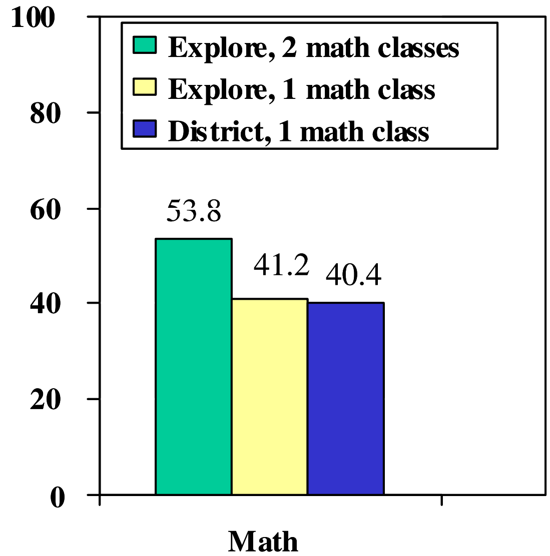
Figure 3: Mean Scores on 9th Grade EWT (1996) for 7th Grade Entrants



The above differences for math and writing are statistically significant. Other studies have found that word processing tools give students more opportunity to organize and clarify their thoughts, and improve writing skills.[15] However any effects on writing skills appear short-lived. By tenth grade, only math scores are statistically higher. And, these superior test scores in math can be attributed to an additional math class that a subset of 8th grade Explore students participated in. Taking this additional instruction into account we find no difference in math test scores, as shown in Figure 4.

[15] Bangert-Drowns, 1993; Reynolds & Hart, 1990

Figure 4: Mean Math Scores on the 9th Grade EWT Scores



Although these results do not look promising, Project Explore did produce other successes. The attrition rate for Explore students was lower than it was for other district students (13% vs. 28%), revealing that one advantage of the Explore program was that it kept students interested and committed. One conclusion is that possibly the Explore program had lower attrition because students perceived the importance of technology in their future careers.

The program also created "Parent University," which made math and science programs, English as a Second Language, literacy programs, expert advice on parenting skills, as well as cultural events, available to family members. Participating parents were offered computer instruction to help improve their professional lives. Several parents were able to get better jobs as a result of the technology training they received. Their instructor noted, "These are positions they would never have applied for had they not attended our classes."

Based on this evidence, one may conclude that the main success of the program for these students was the motivation they found in the novelty of technology and their recognition that computer knowledge is valuable preparation for adult life, both of which would lead to a lower attrition rate.

Additional benefits of technology are found in the Union City study, including increased communication via email among students, teachers and parents, increased collaboration among teachers, additional student opportunities to write and edit, and opportunities to produce multimedia projects.

Case study: Israeli Schools

In 1994, Israel funded a large-scale computerization effort in its schools called Tomorrow-98, with the goal of substantially increasing the use of CAI. "The main focus of this program was on the 'computerization of the education system,' accomplished by 'creating a supportive environment that can integrate information technologies in a range of activities within the school…training teachers to integrate computers in teaching…equipping schools with hardware and software, and replacing outdated incompatible equipment' (Israel Ministry of Education, Culture, and Sport, 1994)."[16] The program included significant teacher training in hardware and software. The target student-to-computer ratio of 10:1 was accomplished in 1998 in targeted schools (those that could make "good use of the computers").

Because CAI infrastructure is expensive and takes resources from other educational uses, assessment of its effectiveness is particularly important. To investigate

[16] Angsrit, 1999

the return on investment, the National Institute for Testing and Evaluation (NITE) designed and conducted a study of tests in math and Hebrew.

The tests revealed that computer-aided instruction did not improve test scores, and in fact, may be less effective than traditional teaching techniques. It may be that CAI needs refinement and polish, but there was no clear indication of any egregious flaws in the employed techniques. The theoretical case for CAI is still being developed, and one conclusion presented in this study was that computers can be a diversion and more of a hindrance than a help to learning.

Case study: 1996 NAEP Mathematics Assessment

This case study opens with an insight into one of the forces driving the computerization of the classroom: "In this age of technological imperative, we do it simply because it can be done. Massive efforts are underway to convert traditional teaching to something that can be delivered via computer. Measuring success has been a simple matter: count the number of computers, divide that by the number of students, and report how the ratio of computers to students has advanced – and it is always advancing. Then close the report lamenting that we don't know much about the software being used on these computers, we don't know how many are behind locked doors, we don't know how many are broken, and we don't know how many teachers really know how to use them (there are no assessments of teacher capability here)."[17]

The author Wenglinsky hoped to do better. In collaboration with *Education Week*, he used "advanced analysis techniques" to isolate the effects of the computer from other factors involved in student achievement. The study data came from the 1996 National

[17] Wenglinsky, 1998

Assessment of Education Progress, a national database. The study is based on a sample of 7,146 eighth-grade students and explores:

- Frequency of computer use for mathematics in school;
- Access to computers and frequency of use at home;
- Professional development of mathematics teachers in computer use;
- Kinds of instructional uses of computers in the math classroom.

Twenty eight percent of eight-graders in the database reported using computers at school at least once a week.

The paper acknowledges that studies that look at the effect of CAI often make no differentiation in the various types of technology programs – such as those that involve intensive professional development or those that focus on higher-order thinking. Furthermore, many evaluations use tests that have not been validated.

Teacher professional development

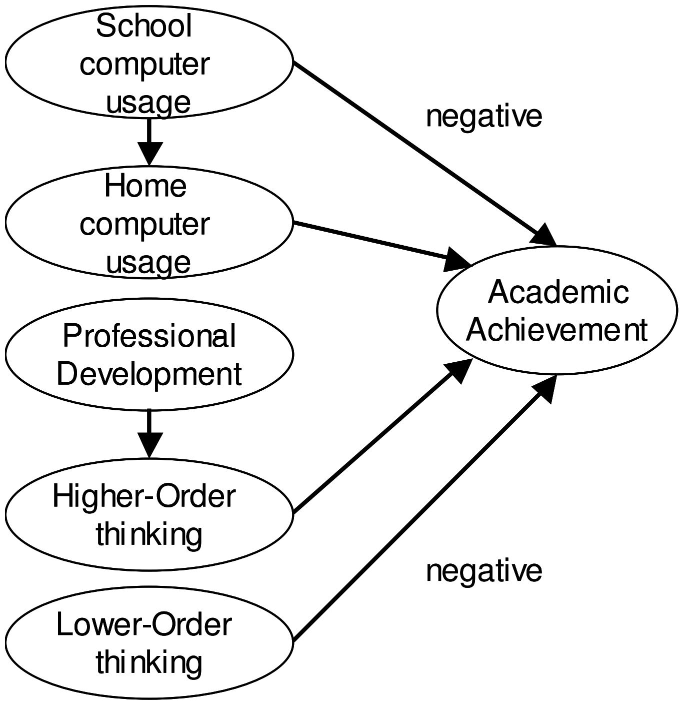
Wenglinsky found that teachers' professional development in technology was positively correlated to the use of computers to teach higher-order thinking skills, and also to academic achievement in mathematics. Thus, teacher computer training is essential to their success as CAI educators, and there is general agreement that there is not enough of it. With a limited budget, it seems the mix of computer installment and professional development for teachers should be adjusted.

Results

Wenglinsky makes a distinction between lower-order thinking skills (such as drills) and high-order thinking skills (such as simulations and applications).

Wenglinsky created the following influence diagram as shown in Figure 5.

Figure 5: Influences on Academic Achievement – Eighth Graders

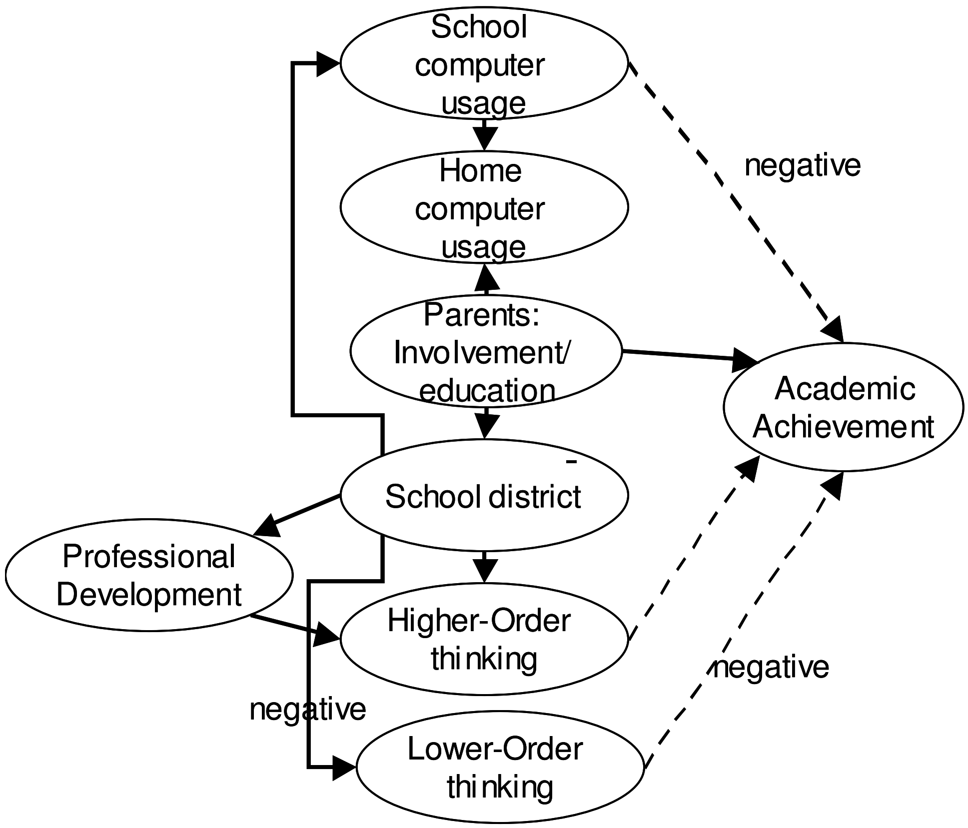


The arrows indicate an influence from one parameter to the other. Arrows signify positive influence, unless denoted "negative."

School computer usage overall was found to be negatively correlated to academic achievement. However, when breaking down this computer usage by lower- and higher-order thinking, Wenglinsky found that higher-order thinking was positively correlated with academic achievement while lower-order thinking was negatively correlated. For teachers to implement high-order thinking with technology, however, professional development is needed.

Wenglinsky also found that school computer usage affected home computer usage, and home computer usage improved academic achievement.

However, I wonder if the actual underlying influence diagram isn't the following.



That is to say, whether and how frequently children use computers at home is strongly influenced by parental involvement. Because wealthier and better-educated parents are more likely than other parents to have a computer in the home and use computers themselves, they are also in a position to yield more positive influence on their children's technology-related learning. Such computer literate parents serve as role models for their children and underscore the value of computers. On a pragmatic level, they can also help their children to use and understand the technology. Parents from higher socio-economic groups are also generally more likely to be involved in their students' education, and more likely to help their students' overall academic growth. Thus, once adding the influence node of parents, the link from parents to academic achievement is drawn, and the link is no longer present from home computer usage and academic achievement.

This conclusion is bolstered by the demographic breakdown of eighth graders with access to home computers (64% of all eighth-graders nationwide):

- Race: White: 69%, Asian: 68%, Black: 51%, and Hispanic: 50%;
- Economic level: School Lunch Ineligible: 72%, School Lunch Eligible: 42%;
- Type of school: Private 77% or public 63%.

All of these factors are known to be linked to parental economic and educational levels. Among students using the computer at least once a week at home (47% overall), these differences mostly fall away:

- Race is: White: 47%, Asian: 49%, Black: 43%, and Hispanic: 43%;
- Economic level: School Lunch Ineligible: 46%, School Lunch Eligible 42%;
- Type of school: Private 51% or public 46%.

Furthermore, wealthier and better-educated parents can afford to live in communities with more affluent school districts (or rely on private schools), and benefit from better-trained teachers. Thus, there is a negative correlation between educated parents and lower-level computer usage. This in turn either eliminates or decreases the link from lower-level computer usage to academic achievement.

Of course, this is only my hypothesis. But it is important to at least realize that other factors may influence this discussion. The paper does, however, acknowledge that technology-rich environments may be different from those in more conventional settings;

thus, gains in achievement may be due to the student background rather than the school or its technology.

It is however disappointing that overall computer use, and in fact, the frequency of school computer use, was negatively correlated to academic achievement. Thus, it is clear that for high school students, using computers as they are currently used can be more of a distraction than anything else. However, using computers in sophisticated ways can be positive.

The actual size of relationships in the diagram in Figure 5 is measured by taking the differences in NAEP scores between the characteristics and dividing by the difference in mathematics achievement by grade levels.

Size of Relationships

Variable	Size of Relationship
Professional Development	0.35
Primary Use – Applications	0.42
Primary Use – Drill	-0.59
School Computer Use	-0.11
Home Computer Use	0.14

Thus, for instance, students who use computers at home are 0.14 of a grade level (about three weeks) ahead of their counterparts.

Furthermore, the size of relationships relative to other characteristics was:

Variable	Size of Relationship
Socioeconomic Status	0.40
Class Size	0.06
Teacher Characteristics	0.07
Professional Development	0.04
Primary Use – Applications	0.04
Primary Use – Drill	-0.06
School Computer Use	-0.05
Home Computer Use	0.07

Case study: A meta-analysis

Krueger compiled a meta-analysis on a series of other meta-analyses that examined the effect of computer use on student achievement[18]. The meta-analyses generally concluded that computer use was positively correlated to student achievement. For example, Kulik and Kulik (1991), compiled a meta-analysis on 254 past controlled studies that looked at the effectiveness of computer-based instruction (CBI), and concluded that, "In 202 (81%) of the studies, the students in the CBI class had the higher examination average; in 46 (19%) of the studies, the students in the conventionally taught class had the higher average." However, Krueger was concerned that, "If, as in the case of computer use, reverse causality is a problem (e.g., more advantaged students tend to use computers), then a meta-analysis is unlikely to be very informative unless the underlying studies have dealt adequately with reverse causality problems (which most

[18] Krueger, 1999

have not)…Discerning cause from effect in the observational studies of computer use and student achievement is nearly an insurmountable challenge for researchers."

Kuger also notes that, the meta-analyses reviewed by Cuban and Kirkpatrick, who concluded, "we are unable to ascertain whether computers in classrooms have in fact been or will be the boom they have promised to be."

After reviewing the various meta-analyses, Krueger concluded that "computer-assisted instruction, when done correctly, can probably help reinforce traditional classroom learning. But the curriculum has to be tailored to the student with clear goals in mind, and CAI may be ineffective, or perhaps harmful, if done incorrectly."

The difficulty in coming to any decisive opinion, however, he notes, is the lack of data available.

Conclusion

To date there are not enough data available to draw any clear conclusions. Given the amount of money spent by government, it is surprising that there is such a dearth of comprehensive, reliable studies conducted. As Krueger notes, "the time is past due for the Education Department to conduct a large-scale, randomized study of the efficacy of computer-assisted instruction to determine which modes of CAI work best, and for which types of students. In the meantime, we putter around with highly imperfect data."

It is clear, however, that we cannot say that technology has improved student learning in secondary education. As schools are normally risk-averse, it is surprising that schools have jumped into this new technology with such speed and investment. Painting with a broad brush, teachers appreciate the individualism of teaching, and tend to stick to the tried-and-true. But schools are also eager to embrace anything that is easy to quantify and label. Another easy measurement is computer-to-student ratio. We know exactly how to get it lower, and we can instantly quantify and discuss it.

Qualitative insights

While no quantitative insights are clear, there are some clear qualitative positives for technology. Tozoglu found positive changes in student behavior observed by teachers working in a technology-enhanced classroom including increased motivation, student interaction, and a greater interest to learn. He bases this on a study by Shoefeld[19] in which 30 inner city fifth-graders used technology to interact with their fellow classmates in new ways. The study found that student motivation increased in tandem with class involvement so that students seemed to enjoy class work better than they did before. [20] Tozoglu suggests two reasons for students' motivation, and both are useful to determine the sustainability, transferability, and long-term educational prospects.

1. The novelty of technology.
2. Student recognition that computer knowledge is valuable preparation for adult life.

Both are valuable considerations when introducing software in high schools. The first motivation is less enduring, as the novelty will presumably wear off. But as we have all seen, no sooner will the novelty wear off, than new technological advancements or improvements appear – assuming schools even keep up with technology advancements. The second motivation is highly sustainable and important. According to a Commerce Department report, already by 1997, more than half of all workers directly used a

[19] Tozoglu, 2001
[20] Schofield 1995 [from Tozoglu, 2001]

computer keyboard on the job. [21] Workers who use a computer at work are paid more than those who do not, and are more highly sought after by employers. Kreuger found that in 1993 “workers who use a computer on the job are paid approximately 15 percent more, on average, than other workers in the same industry who have the same level of education and experience, but do not use a computer on the job.”

Studies also show that when students work on computer-related tasks, interaction among students often increases. For instance, Webb felt that students learn and achieve more through this computer-related group work.[22] It is important to understand the ways teachers shape this interaction, including the location of computers (with sufficient room for interaction to take place), the ratio of computers to students, and how teachers generally handle the educational environment.

Cuban discusses the success of teacher Alison Piro using technology with her students. Technology is beneficial to students in three ways: “by granting them direct access to facts, ideas and primary sources; by linking images and concepts to sound and film, by allowing students to produce creative and professional presentations rather than collages on poster board; and by motivating students, particularly those who would not otherwise be motivated.”[23]

The presence of the Internet and other technology in high schools has exposed students to non-traditional educational experiences, and unique learning opportunities. For instance, a telecommunication project between students in New York State and students in Moscow city schools (MAGI Educational Services, Inc., 1992) had “a

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[21] Kreuger, 2000
[22] Webb
[23] Cuban, 2001

positive effect on student interest in international issues and current events." The project involved surveys, polls, articles, newspapers, research, analysis, and creative writing. The study also included a control group of students, who spent the same amount of time doing research, but without the benefit of any communication with other students in Moscow. It found that the telecommunication students spent more time than the control group of students discussing political or social issues, discussing international events, reading news magazines at home and reading books by foreign authors not assigned by their teachers.[24]

In another study, McClintock states that computers create better learning habits by automatically flagging errors in spelling, grammar, and accuracy.[25] The thought is that students will make errors unless told otherwise, and the sooner the error is pointed out the better. However, it is necessary to see quantitative data before accepting this point. For instance, when my friends and I were students, our teachers caught our errors, which cost us grade points. We manually corrected the mistakes and learned not to repeat them. Today computers can fix spelling errors without even signaling the change to the writer.

Mastery Charter High School

Decision Education Foundation course

Through Decision Education Foundation, I had the opportunity to apply classroom technology myself. As a project leader, I helped to design and teach a course at Mastery Charter High School (formerly High Tech High), a charter high school for underprivileged youth in Philadelphia. The course focused on basic decision-making

[24] Sivin-Kachala, 2000
[25] McClintock, 2001

skills, and was taught by seven of us volunteering as members of the Decision Education Foundation.

We used Power Point presentations created in advance as a classroom-teaching tool. I saved them to an Internet email account, retrieved them on the computer in the classroom, and projected them with a computer projector. I somewhat agree with veteran teachers I have heard who say that when the lights go down and the PPT slides go up, the kids tune out. Although keeping students' attention with dimmed lights was difficult, I found that with the right PPT slides it is possible to pique student attention, rather than dampen it. Furthermore, as with all technologies, the worry is that if the technology fails, the lesson is lost. I always came prepared with paper copies of the PPT presentations in case we encountered any difficulties.

Students also created their own PPT presentations. Gone are the days of messy glue, paper cuttings on the floor, and general chaos. Instead, students were diligently working on their computers to create the slides. Although students were focused on their project, and found pleasure, I'm not sure if they spent more time on *substance*. They preferred spending their time looking for pictures for their presentations.

We also used the Internet as a class exercise for research purposes. Students found the exercise particularly exciting. As discussed before, when students are learning how to use technology, learning valuable skills, they pay more attention.

Additionally, we wanted to use the computer in more sophisticated ways. We had a game theoretic exercise planned in which students play against each other. Although the software application existed, in the end I did not use it. It took me two weeks to get access to the relevant Internet site and download the software, only to find that the software was far from intuitive. Given the limited time, we were not able to incorporate this into the lesson. Finally I fell back to a paper-based version of the game. It was clear that the future must provide bug-free, user-friendly educational software.

In addition to my time in the classroom with students, I tutored one of the students and saw first-hand how he used technology. Not all of it was positive. For instance, he was so accustomed to his calculator, that he could not multiply 10x10 in his head. Perhaps he can always use his calculator, but I'm not sure if he wants to pull it out when getting change at a store, or when figuring out how much he should tip at a restaurant. Just as troubling, I saw that he used his online math tutorial to find the answers to his homework without learning it himself.

Interview with Scott Gordon, CEO

As a result of my work at Mastery Charter High, I was able to interview Scott Gordon, CEO of Mastery Charter High, to hear his first-hand experiences.

Mr. Gordon sees three goals for technology in his school:

1. <u>Make curriculum more engaging and stimulating for students.</u> Mr. Gordon believes technology has been tremendously successful in this area. Students find it appealing to work on a computer, and are doing tasks they would not have previously done. For instance, students are more willing to write a paper using word-processing technology. The time they take to edit their own work – and even each other's work – has increased. They enjoy the ability to illustrate their writing with graphs and tables.

2. Make education more student-centered by customizing the educational experience for them. To date, this goal has not been met at MCH. Mr. Gordon feels the technology doesn't yet exist to achieve this goal on a sustained basis. He found a few good software players, but the tools were not engaging enough and, at about $1000 per seat, too expensive. Mastery Charter High strives to have lessons that are hands-on, active, and apply knowledge. Mr. Gordon would like more software that teaches "skills for life" such as critical thinking. Trying to find the right lessons and projects are time-consuming. Teachers may end up using technology in less effective ways, which can lead to wasted time and diminished value. Furthermore, students can be easily sidetracked by computer glitz rather than focus on content.

3. Help teachers to better manage the back-end or administrative business of teaching, including data management, presenting lesson plans, and a "robust network" enabling easier communication among teachers. Mr. Gordon sees this as a great success. Teachers communicate electronically with ease, trading information effectively and efficiently. In fact, technology has increased camaraderie. This effect is a huge selling point that Mr. Gordon feels is overlooked in papers. He feels Mastery Charter High could never return to operating without technology.

These successes notwithstanding, Mr. Gordon points out that management of technology costs substantial money and time, and it's no easy feat to maintain a network for 300 students. The school cannot afford the amount of IT support it would like.

Mr. Gordon's two pieces of advice to other schools are:

1. "Keep everything simple." Limit the technology opportunities to what is manageable (e.g., can't log in from home, can't download music files, etc.) Begin with lowered expectations and focus on the "80%" rather than the "20%." Make sure web applications are easy to use. Realize that finding quality curriculum materials using technology is an enormous undertaking. Limit everything and specify for teachers exactly what will work—teachers should teach, not experiment.
2. "Be cheap." There's no reason to have the latest hardware. Mastery Charter High used to budget about $300 for a CPU, now the school accepts donated equipment, or budgets at most $150 per CPU. Older computers can handle everyday tasks. Budgets for monitors and peripheral equipment are also constrained. This allows improved focus on training and IT support.

Mr. Gordon hopes that in five years there are better curriculum applications – those that are more customized, more engaging, and offer more simulations. To reach this goal, MCH is collaborating with software companies to undertake some customized curriculum development. Unfortunately, MCH has not found much opportunity to collaborate with other schools. As a trailblazer in this area, MCH has not found many other schools with which to partner.

Interview with William Walker, IT manager

I also interviewed Mr. William Walker, the information technology manager for Mastery Charter High. He usually recommends one IT staff member per 100 users. This means four IT staff members at MCH (300 students and 60 teachers and administrators). To make the job even more challenging, some students sabotage and damage the hardware, or try to hack into the system. Installing technology is relatively easy, but maintaining it is quite a challenge. He sees technology as a two-edged sword.

Mr. Walker leveraged student interest to help maintain the technology system by creating a “tech club.” He teaches a select group of students advanced skills including rebuilding CPUs that are donated to the school. The return on investment is high for Mr. Walker and the students alike. He gains valuable support managing the school’s computer network and the students, who are recommended by their teachers to the club, love the experience. The average student at MCH never touched a computer before coming to the school. Yet students in the tech club take an enthusiastic interest in managing the technology, while learning solid workplace skills.

Mr. Walkers’ advice to schools:

1. Research and test a product before buying any large quantity. (This applies to both software and hardware.) It won’t always live up to expectations.

2. Make sure teachers have adequate training. Mr. Walker doesn’t have the time he would like to devote to this. Teachers need to find the time to pick up the user manual and learn on their own.

3. Make sure teachers know how to back up their work. Every semester, Mr. Walker gets a least one teacher who has a problem with the software that holds students’ grades and never had a back-up made.

4. Make sure to have a back-up lesson plan if the technology isn’t working. Teachers become extremely dependent on the technology. Before contingency plans were made, when the network wasn’t running, teachers’ lessons were halted.

5. In concurring with Mr. Gordon, Mr. Walker strongly believes in keeping it simple.

Conclusion

It is clear that technology in schools has not yet shown a demonstrable ability to raise test scores. But it is also clear that students gravitate toward technology. They are more motivated to learn – both due to technology's novelty, and to the importance students place on it. Whether this motivation is more of a distraction than a benefit is yet to be seen. In the meantime, schools would benefit from following Mr. Gordon's approach of simple and cheap, while exploring new ways to use technology and discovering new successes and opportunities through classroom pilot programs.

Inappropriate content

One major concern with Internet availability in schools is student access to inappropriate materials. The government has played an important role in assuaging these concerns. Under the Children's Internet Protection ACT (CIPA), no schools receive Education-rate (E-rate) discounts unless they certify that they are enforcing Internet safety policies, such as the use of filtering or blocking software. The E-rate program, established in 1996, makes services, Internet access, and internal connections available to schools and libraries at discounted rates on a sliding scale, based on income levels of students, and location (urban or rural). By 2001, 96% of public schools with Internet access used some type of software to prevent students from accessing inappropriate Internet materials.

Distance Learning

The Internet has become an invaluable tool for "resource-based learning"[26]. Ryan cites six ways in which the Internet supports research-based learning: delivering courses; identifying and using resources; communication and conferencing; activities and assessment; collaborative work; and student management and support.

Using the Internet to deliver course content has become the most powerful application of computer technology. Distance education helps in the quest for affordable, accessible education. In 2002, 33 percent of US public schools offered some form of distance-learning programs[27]. This opportunity for distance-learning is more abundant in rural areas and in areas with higher concentrations of students in free or reduced-price lunch programs (Market Data Retrieval, 2002)."[28] Canada, with her rural communities, is known as a leader in distance learning and has Internet-delivered and complemented courses in secondary education throughout her provinces[29].

Thus, while a traditional classroom brings students to education, a virtual classroom brings education to students. Virtual classrooms share interaction "spaces" created within a software package, where teachers lecture and group discussions take place. There can still be a communication structure, including office hours. In addition, the software typically has the ability to administer, collect, and grade tests.

The advantages of a virtual classroom include:

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[26] Ryan, 2000
[27] Staresina, 2002
[28] Staresina, 2002
[29] Jones, 1998

Flexibility. Students don't have to be at the same place at the same time. Furthermore, coursework can be done on one's own schedule.

Additional Communication. A virtual university is available around-the-clock. Unlike a traditional classroom, in a virtual classroom, discussion and communication about the course become a continuous activity. (Of course, a traditional classroom in which students have Internet access can create a similar environment.)

The burgeoning opportunity for distance learning has led to the creation of "virtual schools." For instance, Florida Virtual School, one of the largest virtual schools in the US, offers 60 high school courses "ranging from algebra to Latin." Fifty eight percent of FVS students surveyed felt the courses were "better" or "much better" than courses in traditional high schools (*Technology Counts*, 2002).

Some online opportunities are particularly creative. Sun Microsystems has produced virtual classroom software packages that allow nine to twelve students in separate locations to attend class together live from their desktops, using audio and video cards.[30]

Little research has been done to look at the effectiveness of distance learning. One review of the research on distance learning in college and high schools indicates that, "while there is no suggestion that students fare better in distance-learning courses, they appear to be as effective as courses taught in conventional classrooms (Institute for Higher Education Policy, 1999)."

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[30] Jones, 1998

Although interaction with other students is possible, there may still be room for improvement[31]: In Berg's 2001survey of distance-learning class participants, 24 percent of students either disagreed or strongly disagreed with the statement, "Courses include significant interaction with other students." Additionally, 97% agreed or strongly agreed that, "I learned as much or more in this distance learning course as in an average traditional face-to-face course" (vs. 60% for a correspondence course). Ninety three percent agreed or strongly agreed that, "Critical thinking skills were utilized and developed in this course." (vs. 80% for correspondence classes). Thus, while the survey suggests computer-based classes significantly improved the learning ability over correspondence classes, it also suggests that critical thinking was not improved in equal measure.

Nickerson suggests a possible outgrowth of online education – an acceleration of the already declining prestige of traditional university degrees. He points out that it was more impressive to have a high school diploma fifty years ago than it is to have a college degree today. Thus, the ubiquity of university education has, "diluted the significance of a college degree." It is my belief that this dilution will simply result in an increased differentiation in the types of college degrees, and increased importance of college "brand names." Regardless, Nickerson believes if technology helps "more people get an education, it could further degrade the value of that education." But it would be very difficult to find secondary school educators who lose sleep worrying about educating too many students.

[31] Berg, 2003

Once the infrastructure is in place worldwide, virtual classrooms may provide the only economical solution to satisfying the increased global demand for education. However, for distance learning to succeed, students cannot become passive learners, but must provide appropriate input during the virtual class. Class participation would be necessary in order to advance. It is beneficial, Jones notes, when the virtual classroom requires students to interact with each other, and goes on to suggest that interaction among students may be achieved even more easily online than it is in a traditional classroom.

Innovative technology applications for high schools today

There are some exciting and creative uses of technology germinating in high school education already. The examples below involve curriculum designed to help students make better decisions in their lives (a quality that is hard to measure in a quantitative study).

B.J. Fogg, Director, Persuasive Technology Lab at Stanford, has coined the term "persuasive technology" to mean "interactive computing systems designed to change people's attitudes and behavior." [32] Students learn through simulated observations and can use programs to reinforce target behavior. One example program is the "Baby Think It Over Infant Simulator," using a computer that looks and acts like a baby. Students are asked to care for a computerized doll for two weeks to simulate the experience of parenting a real infant.

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[32] Fogg, 2003

Ms. Alice Ray, co-founder and CEO of Ripple Effects has created software to help students evaluate their social behavior and determine their values and the decision-making processes they use in their own lives.

Dr. Sam Savage, Professor, Management Science and Engineering at Stanford University, has developed a software package called Analytica to model and evaluate decisions.

Technology and the education gap by wealth

According to the National Center for Education Studies, by 1999 there was a 35% gap between the poorest and richest schools in having Internet access: 73% of schools in which less than 35% of students qualify for reduced-price lunches have Internet access, vs. 38% of schools in which more than 75% are eligible for reduced-price lunches.[33] However, by 2001, this gap has significantly shrunk to about 10 percentage points: schools with more than 75 % of students eligible for a reduced-price lunch had 79% of instructional rooms connected to the Internet, however, schools with less than 35% of students eligible for a reduced lunch had 90% of rooms connected to the Internet.[34]

Similarly, the ratio of students to computers is 4:9 in schools with less than 35% of students eligible for reduced-lunch. This compares favorably to 6:8 in schools with greater than 75% of students eligible for a free or reduced-price lunch.

Yet there are still a number of additional considerations when evaluating the "digital divide." For instance, are minority students equipped for the changing environment? If Nevens is correct in his assertion that technology will change the roles

[33] Nevens, 2001
[34] Tabs, 2002

of students and teachers, making students more independent in the self-directed pursuit, then minority students will indeed be at a disadvantage.

Wenglinsky states that minority students are less likely than other students to be exposed to higher-order computer uses (e.g., analytical reasoning rather than tutorial applications). This may be due to the fact that urban and lower income students were less likely to have mathematics teachers who had had professional development in technology[35]. But other evidence suggests that perhaps this is not due to professional development of teachers, but rather may have more to do with other factors. The percentage of students whose teachers reported any professional development in technology in the last five years (76% overall), which was almost identical when compared:

- Along socioeconomic lines: 75% for students who are school lunch ineligible; 72% for students who are school lunch eligible.
- Or by race: 77% white; 77% Asian; 76% Black; 76% Hispanic.

However, it is possible that teachers' professional development in technology may be emphasizing different areas, or of disparate quality.

As shown below, students from higher socio-economic backgrounds are more likely to use computers for simulations and applications than for drills and practice.

Simulations/Applications

Twenty-seven percent of eighth-grade students use the computer primarily for simulations and applications.

[35] Wenglinsky, 1998

- By race this breaks down to be: 43% Asian; 31% White; 25% Hispanic; 14% Black.
- By lunch eligibility this breaks down to: 33% ineligible; 22% eligible.
- Or by school type: 30% private; 27% public.

Drill/Practice

Thirty-four percent of eighth-grade students use the computer primarily for drill and practice

- By race this breaks down to be: 27% Asian; 30% White; 34% Hispanic; 52% Black.
- By lunch eligibility this breaks down to: 31% ineligible; 34% eligible.
- Or by school status: 10% private; 36% public.

Furthermore, minority students are less likely than others to have access to a home computer.

Implications for Managers of educational technology

As we have seen, managing technology in secondary education is far from simple. Schools face broad uncertainty regarding how technology will be used and for what benefits. There are few resources available to help find the right software applications for a given task or lesson, along with tight budgetary constraints. Teachers often do not receive sufficient nuts and bolts training about this new educational agenda, leaving them excluded from the decision-making process and unenthusiastic about the new educational opportunities technology can provide. Managers left in this confusion might either jump in without clear goals or wait it out. In either scenario available resources are wasted.

This paper recommends four steps to help manage technology better in secondary education:

1. Determine the outcome desired for technology;
2. Realize potential pitfalls and plan accordingly;
3. Understand the incentives, positions, and opportunities for all the stakeholders;
4. Undertake scenario planning to create possible options, analyze associated benefits and risks, and determine the best strategy for moving forward.

Step One: Determine the outcome desired for technology

One can argue that computers in the classroom and the associated educational expectations are repeating the familiar computer hardware/software PC cycle: Every advance in CPU speed, bandwidth and architecture was developed and marketed before software was adapted or even written that could take advantage of the new advances. At the time this paper was written, AMD had just released a 64-bit personal computer chip code named Sledgehammer.

Currently, however, no desktop computer software exists that can take advantage of this next big chip concept. Moreover, at least one reviewer cautioned against buying the Sledgehammer chip before Microsoft releases its 64-bit version of Windows (scheduled for release next year.) Yet Sledgehammer is on the market now and buyers are queuing up. We know from past experience that it’s only a matter of time before new software is written and current software is modified. Schools are repeating this cycle. They have the hardware, but they don’t have the software to take advantage of the potential. How can they get the software? One effective paradigm can be applied to help answer this question – the business model of analysis, design, development, rollout, and maintenance.

Dr. Cuban suggests that four questions must be answered before creating the right roadmap for success.[36]

1. "What do we want to use computers for in our classrooms?" Do we want to use computers to help students master basic skills and acquire factual knowledge? To raise test scores? As a tool to create student-centered teaching and learning? To make our children more computer literate?"

Currently, researchers investigating the successes of technology in the classroom are answering this question. They are testing whether technology has improved test scores, motivated students, or enhanced learning. But before researchers can measure successes, school boards, policy makers, practitioners, and parents must decide what goals are to be achieved, and therefore what the researchers should test. A preliminary list of possibilities includes:

1. Improving test results? (Math? English? Standardized state exams?)
2. Preparing students for the information age?
3. Making learning more fun and motivating students to learn?
4. Acting as another teaching resource?
5. Improving student teamwork skills through computer projects?
6. Helping students and teachers (and parents?) communicate better? (website, intranet, email, etc.)
7. Offering a greater breadth of opportunities from which to learn? (Interactive activities on the Internet)
8. Making learning easier? (research, write papers, etc.)
9. Easier for teachers to do the back-end "paperwork?"

[36] Cuban, 1998

2. “Can we reach our goals at less cost – without additional investments in technology?”

Studies do not compare computer use with other educational options, such as peer tutoring or increased parental involvement. The cost effectiveness of the computer is not addressed. (Furthermore, most studies look at computer usage with one teacher versus no computer usage with *another* teacher, thus creating lack of control and comparability in the study.) Until schools recommend studies that examine the cost-effectiveness of computers, it is difficult to judge whether alternatives to computers can secure the same results at a similar or even reduced cost.

Should computers be cost effective when compared to a teacher? For example, let’s assume one desktop computer, software, infrastructure and maintenance costs $5,000 and lasts five years, thus requiring a budget of $1000/yr. Let’s also assume that one teacher costs $40,000/yr. Given these assumptions, a school could have either 2 teachers and 20 students per classroom with no computer, or 1 teacher with 40 students and 40 computers.

3. “Will computers help create the type of students and citizens we seek?”

According to Cuban, there is little or no research that answers this question. What is needed is an understanding of how technology best fits into the classroom.

4. “Through what means can we achieve our desired results?”

What type of software do we need? Should students work individually or collaboratively? How can we keep students engaged but not distracted? Once again there is no clear-cut answer in the current literature. However, once schools start considering these questions and evaluating pilot programs with this lens, they can help direct software companies to create successful packages for the classrooms.

Step Two: Realize potential pitfalls and prepare accordingly

Historically, US schools have not worked in a competitive marketplace, and have not been subject to outside pressures to embrace, adapt, and evolve. As the education marketplace has been traditionally stable, schools' survival has been largely assured. However, the winds of competition are now blowing across secondary schools. School vouchers, magnet and charter schools, home schooling – and an increased awareness of "global competition" – are pushing educators to find technological enhancements for the classroom. Schools can no longer remain behind the S-curve.[37] But like a ship in uncharted waters, adopting emerging technology can be risky and uncertain. If implemented incorrectly, the school could flounder. Schools therefore must recognize and learn how to avoid the pitfalls of emerging technologies. Dr. Paul Schoemaker and Dr. George Day determined four critical pitfalls to avoid when businesses embrace emerging technologies: delayed participation, sticking with the familiar, reluctance to fully commit, lack of persistence.[38] Their insights have relevance to those schools trying to grasp the intricacies of applied technologies.

Delayed participation. Companies often delay embracing new technology because it begs uncertainty – and with uncertainty comes risk. The temptation is to wait until others have first invested in the technology and then go to school on their successes and failures. Almost instinctively, we all want to stick with the tried-and-true. That said,

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[37] Moore, 1999
[38] Day, Schoemaker, 2000

schools have already recognized the need to examine new technologies. The computer-to-student ratio is already 4-to-1. Most classrooms are connected to the Internet and use software programs as part of the classroom experience. They are jumping into technology without evaluating less aggressive alternatives. Thus, delayed participation is not an issue for schools.

Sticking with the familiar. Businesses are tempted to "stick with the familiar" because of the difficulty in seeing how the unknown can be better than what is in hand. Even though schools have brought computers into the classroom, they are not taking full advantage of all the educational possibilities, because the full potential of computers in the classroom is not yet clear. The myriad applications and uses of computers in the classroom are just now being recognized or developed. We are perhaps "blinded by its current look and feel, or by the current shape of the market." Just as businesses go outside of themselves to become familiar with the unfamiliar, schools must also draw upon new sources to widen their perspectives.

The solution: schools need to first decide what problem computers are supposed to solve. Once they define the problem, they are in a position to find the solution. Is the goal to improve test results or increase student motivation? Once the problem is clarified, schools should "bring in perspectives from experts in unfamiliar technologies, market and strategies" and "draw upon new sources of ideas." This perspective includes: software and hardware companies, think tanks, university schools of education, etc. They can also start a yearly forum to exchange ideas and discuss progress. Schools and software companies can work together to elicit scenario planning, posing such questions as: What would the curriculum be like with certain technological inventions? Working alone, schools may not be able to excite software companies. However, schools can partner with other schools in their local community, state, or elsewhere in the country, and can reach larger consensus on specific needs that software companies can address.

The CEO Forum also recommends collaborative effort. "The CEO Forum encourages teachers, students, administrators, school board members and parents to use the STaR Chart in their schools to help identify their schools' current technology profile and then, by prioritizing education objectives, develop an educational technology plan that will maximize available resources as the school moves forward to integrate technology into the classroom. [Additionally] the CEO Forum urges universities, policy makers, research institutions and the private sector to work together to define and develop state-of-the-art measurement tools that will enable a realistic assessment of the effect of technology integration on the process of teaching and learning."[39]

Reluctance to fully commit. When a business fully commits and embraces a technological advance, it requires buy-in from all divisions and management levels to develop, apply, and market the new technology. Just like business, the successful education centers of tomorrow will learn to become innovators. Generally speaking, schools are only just now – and hesitantly – reaching out and forming alliances with the universities, software development companies, teacher certification boards, parents and the larger community. This outreach means focusing not only on what technology can do for us now, but also where it can take us in the future, so that everyone is working toward a shared vision.

[39] CEO Forum on Education & Technology, 2001

Schools have not fully committed. They have invested heavily in the hardware and connectivity. But success means additional investment in training and IT support, along with finding the best software and applications available. It may also involve schools assessing their own needs and creating ideas for new software and applications. But cash-strapped schools currently can't afford to give any more money, especially when they haven't yet seen the results expected.

The solution: Schools need to create and manage their strategic options. Schools should reallocate their technology budget. As Mr. Gordon suggests, one practical solution is to reduce the spending on hardware by getting donated computers. Also, consider only doing a few pilot programs rather than rolling out new technology programs throughout the school. This extra budget would allow for additional training and support. The schools' primary curriculum advisor should also invest time and energy to finding the best software and applications for those pilot programs.

Schoemaker and Day also recommend thinking outside the box. That is, schools should ask, "Are you too well fitted to the core business, and incapable of operating out of equilibrium? An optimal fit to the present business may not be an optimal configuration for the long-term survival." Schools are trying to think outside the box: desks are now placed in clusters for team learning, and technology activities use multi-media. But perhaps we are just at the cusp of the opportunities available, and thus we need to continue to push ourselves to think of new ways of learning.

Lack of persistence. Having overcome the first three hurdles, businesses often fall victim to a lack of persistence. This happens when early forecasts and milestones are missed, and enthusiasm turns into doubt and retrenchment – a hard-to-overcome feeling of tossing good money after bad. Schools use a different currency but they still face the same trap and must be prepared to invest in a total effort, with all of the stakeholders involved. As Steve Jobs observed, “It takes a long time to achieve overnight success.”

Schools continue to advance their technology agenda and generally do not lack persistence. Yet this unwavering commitment to the prescribed goal – regardless of the tangible payoff – may in fact be a detriment. Schools would surely benefit by adopting a more restrained approach that involves careful evaluation of all possible avenues.

Summary

The question becomes, how can schools pick the best that technology has to offer and bring it to the classroom? Success requires a commitment to change, support for change at all levels, and the ability to craft the best solution out of a wide range of options. Understanding the pitfalls will help schools realize their educational goals by avoiding the mistakes of others and finding solutions which best fit their needs.

The four pitfalls and solutions are summarized in the following table:

Pitfall	Applicability to schools (1=large pitfall, 2= relevant; 3=not the case)	Solution
Delayed Participation	3. Schools are jumping into technology before evaluating it	N/ A
Sticking with the familiar	2. Schools often use technology in traditional ways because innovative approaches haven't yet been fully developed	Work with software developers. Define the goal for the software application. Partner with other schools to provide incentives to software companies to create the applications
Failure to fully commit	1. Schools won't succeed until they work with software companies and devote more to training and support	Find ways to decrease the hardware and infrastructure costs: use donated computers, run pilot programs first, and use the saved money for increased training and support
Lack of persistence	3. Schools continue to pursue technology without seeing successful results	N/A

Step Three: Understand the incentives, positions, and opportunities with all stakeholders

Cuban cites a successful technology magnet school (that boasts a signature inter-disciplinary program within the school) because stakeholders were involved.[40] "Staff, business leaders, parents, and students had hammered out a mission statement, school-wide goals, and specific curricular standards." By all accounts, it was difficult to create school-wide goals, and teachers argued vehemently over academic and interdisciplinary standards. However, in a tribute to the benefits of perseverance, consensus, and long-

[40] Cuban, 2001

term thinking, within five years, the teaching positions at the school became some of the most sought after in the district.

In order to succeed, it is important that all stakeholders are considered and involved in the process – including the school board, the principal, teachers, parents, and students. Further, schools need to communicate or seek out from other schools what really works.

School Boards

As highlighted in the CEO Forum, there are four cycles of technology integration, and all of them involve collaboration with the school board. The cycles include planning, investigating and experimentation; initial capital investments; readjustments; and the emergence of new work and organizational models. School boards must work with principals to determine how best to find and allocate funds. In forecasting future expenses with technology, they should be careful not to underestimate the cost of maintenance and support, as technology will fail without it. For instance, if maintenance and support costs 30% of the cost of the computer, then it is better to have 30 computers with maintenance and support than 39 computers without maintenance and support.

It is also valuable for school boards to draw on outside experts offering different perspectives. Day and Schoemaker suggest that firms (here schools) ask the following questions:

- "How can your firm bring in perspectives from experts in unfamiliar technologies, markets and strategies?

- How can managers draw new sources of ideas (periodicals, conferences, etc.) to break out of their narrow perspectives?"[41]

Following this advice, school boards should consider collaborating together, and even setting up conferences to share perspectives.

Further, school boards should help set up the most viable environment possible, by advocating certain incentives, culture, and values, in order to adopt technology successfully. Dawes notes seven features of institutions that make a difference in the implementation and application of technology in the classroom.[42]

1. Quality of management. This includes high-level support demonstrated to the teacher, an effective steering group, a development plan, and overall training.

2. Quality of other project partners. This includes effective human networks, articulated roles for all participants, and teacher control over curriculum content.

3. Stance towards IT generally. This includes a clear IT policy, and dedicated IT staff members that provide prompt and effective technical support.

4. Current and anticipated levels of financial and physical resources available and required. This must have a level and predictability of long-term financing and maintenance costs.

5. Quality of new technology available. High quality technology will have an ease of use by both teachers and learners, be reliable, and its educational benefit must be immediately obvious to teachers.

6. Dominant educational and social philosophy. The philosophy is not just about the importance of social development and community involvement aims, but also its approach to funding, and cooperation with other institutions.

7. Match between the technologies available and the circumstances and priorities of the educational institution. The technology must naturally be suitable for

[41] Day, Schoemaker, 2000
[42] Leask, 2001

educational purposes, compatible with current resources and project partners, and available at a good physical location within the institution.

Principal

Reksten contends that for successful implementation of technology in education, schools must implement Lead Management.[43] The Lead Manager "uses persuasion and problem-solving and spends his or her time trying to improve the school so that workers will want to do quality work." Furthermore, there is a greater focus on the needs of the teacher rather than that of the administrators. Reksten found that "teachers felt that collaboration was fundamental to generating innovative practices." Successful collaboration strategies not only provide the support structure for the immediate implementation of technology, but also maintain performance in the long term. Examples of collaboration strategies include planning together, peer coaching, sharing about the teaching practice, and a generally collaborative school culture. In this environment, teachers can share ideas and have a support base from which it becomes safe to try these new ideas.

To prepare staff for a technological change, Resken encourages principals and school leadership teams to ask the questions: "What is our view of leadership for technology? What is needed at our school to create a collaborative workplace? What is our view of curriculum? What is our view of how technology integrates with the curriculum?" The first step for the principal is to facilitate a workable plan that outlines the specific objectives of the curriculum, by creating a supportive lead management team within a collaborative culture.

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[43] Resken, 2000

Teachers

Part of the difficulty with implementation is that teachers are fairly autonomous. Moreover, their academic discussions are primarily within their departments. Cuban quotes a principal who explained, "teachers are generally not aware of standards that exist outside of their departments…[and] the efforts of individual programs have not been converted into systematic, school-wide reform – especially, she might have added, reforms that targeted improvements in students' academic performance."[44]

If computers are classroom tools like any others, then computer-based instruction will not be successful without teacher participation. As Cuban notes, this creates a conundrum for school reform, as teachers are both the problem and the solution. According to the current paradigm, computer-assisted instruction (CAI) is supposed to improve teacher performance by improving test scores. Yet, CAI cannot be successful without teachers playing a pivotal role in interactions between student and machine.

However, teachers report they don't feel prepared for the computer classroom, and that they need more support. Despite the astounding trends of Internet access in the classroom and low computer-to-student ratios, in 2000, only 33 percent of primary- and secondary-school teachers felt at least "well prepared" to integrate "high-quality digital content" into their lessons.[45]

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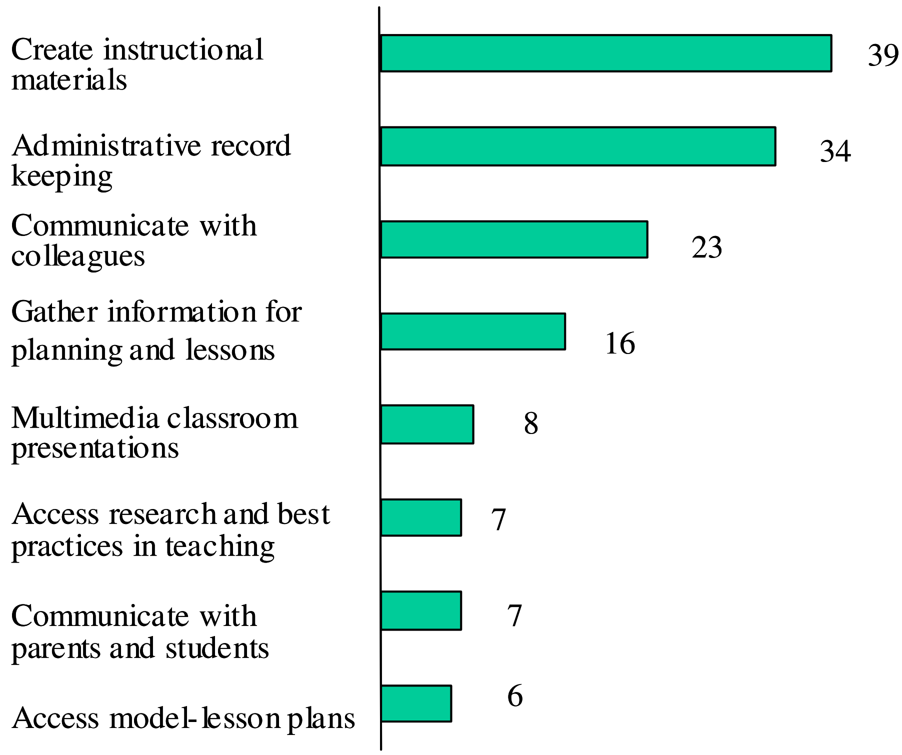
[44] Cuban, 2001
[45] Nevens, 2001

According to the *Stats in Brief,* one half of technology used by teachers is for administrative purposes.[46]



Pillai finds in his study that educators who successfully integrate instructional technology into their classrooms "tend to hold advanced degrees and certification, participate in on-site training, and are generally comfortable with the Internet."[47] Demetriadis identifies three conditions necessary for teachers to incorporate technology into their classrooms, which he labeled: Effectiveness, Disturbances and Control.[48]

1. Effectiveness: "Teachers must believe that technology can more effectively achieve or maintain a higher level goal than what has been used."
2. Disturbances: "Teachers must believe that using technology will not cause disturbances to other higher-level goals that they evaluate as more important than the one being maintained."

[46] Stats in Brief, 2000
[47] Pillai, 1999
[48] Demetriadis et al, 2003

3. Control: "Teachers must believe that they have the ability and resources to use technology."

Demetriadis notes that Pelegrum (2001) further investigated the obstacles to introducing information education: "1. Insufficient number of computers. 2. Teachers' lack of knowledge/skills. 3. Difficult to integrate in instruction." This is similar to Ely's (1993) observations on conditions required for implementation: "1. Dissatisfaction with the status quo. 2. Existences of knowledge and skill. 3. Availability of resources."[49]

Demedriadis believes that the major problem for teachers encountering and incorporating technology into their classrooms was "to be accepted by regular members of school life, and find necessary resources for their training (taking into account that the whole training project was on a voluntary basis)." All teachers unequivocally agreed that the role of school principal had been very important to successfully incorporating technology into their classroom. "Positively acting headmasters intervened and offered solutions to problems or newly encountered situations (e.g., allocated appropriate time for training sessions, encouraged school teachers to attend, enhanced perceived importance of the project)." However some headmasters "exhibited a bureaucratic (and even possessive) attitude in the management of school resources, especially in relation to availability of computer laboratory and they were generally unwilling to help and facilitate teacher-mentors."

The Demetriadis study reveals that many teachers requested an official acknowledgement of their technology learning efforts, such as a certificate for their personnel files. Teacher-mentors also suggested that a more official program profile would greatly improve the perceived importance of the training, and increase

[49] Demetriadis et al, 2003

participation and commitment. These comments aside, Demetriadis also points out that "teachers seem to have totally accepted the necessity of technology education use in teaching."

Thus, for teachers to succeed in using computer technology, they must: 1. Get necessary training and technical support, including a computer technician available at the school or at least with the school district. 2. Be recognized for undergoing that training. 3. Create a network of other computer-using educators in the school.

No literature that I found documented teacher advancement, promotion – or even a change in status – as a result of additional technology training. Perhaps teachers who invest their time to learn the new technology are intrinsically more motivated and therefore have already secured tenured or senior positions in the school hierarchy. Or perhaps any teacher who is able to convince the principal to get funding for expensive software, or exert influence over the direction of technology in the school, has already won the respect of the principal. Or maybe there is not a "tit for tat" acknowledgement or payoff or reward for teachers who take the initiative, and that is part of the overall problem.

I have also heard anecdotal evidence from a school in Prince Georges County. A foreign language teacher ran the school TV station. How did he get this position of power within the school? He was an expert teacher, an early technology enthusiast, and was well respected by the administration.

Parents

Both parents and students are the "customers" or "consumers" of the education that schools offer. As an important stakeholder group, parents should play a role in helping schools determine how technology should be used. Parents need to recognize that having a computer-to-student ratio of 1-to-4 is no guarantee that their children are receiving a better education. Rather, parents should be empowered with information enabling them to carefully monitor the budgetary decisions made by their children's schools regarding technology use. Parents who have the opportunity and resources to teach their children about computers at home naturally give their children a leg up in the classroom.

Students

If students are to be vocal about their needs for computer technology, they should both educate themselves regarding the uses and successes of computer technology in the classroom and set clear goals about what they want computer technology to help them accomplish. For instance, a student who wants computer technology to help educate him and prepare him for entering college has very different computer needs from one who is using high school as a trade school and plans to enter into an IT job immediately after high school.

Most of my students at Mastery Charter High were motivated to attend college (often they were the first in their family to do so). Given their interest in college, I was disappointed to hear that some students were considering leaving MCH because they felt it lacked computer training they sought, such as Cisco certification. They did not realize that specific technology training would be less important for college admissions than broad preparation.

Step Four: Planning ahead

In his paper Technology in Education: Looking toward 2020 (1988), Nickerson infuses technology with a potential to open new and improved ways of presenting information that are better suited for human understanding than those otherwise available. He writes, "with the computer comes the possibility of representational media that are dynamic, adaptive, and interactive to degrees not really feasible in the past. One can easily imagine a facility that would permit the user to move readily among various representations of a given entity (structure, process, event) examining it from different perspectives at different levels of detail, accessing, clarifying, or amplifying information that itself is available in a variety of forms (text, pictures, simulations.)"[50]

There are particular benefits to a simulated lab over an actual lab. The advantages include the ability to compress or expand time, the spatial scale, cost or safety improvements, and convenience. That is, information technology can create an artificial world that resembles or differs from the real world in a desired way.

Looking to the future, Nickerson's view of technology in the classroom suggests several important changes are on the horizon. He predicts the obsolescence of some existing knowledge and skills, only to be replaced by entirely different types of training. Technology, in Nickerson's view, could pose a threat to the teacher's unique role as knowledge dispenser or learning facilitator in the classroom. Yet he also acknowledges

[50] Nickerson, et al., 1988

that it can provide new tools and opportunities for innovation, relief from the burden of certain mundane chores.

The future could involve new types of professionals. In addition to IT roles, there may also be school-community brokers, to help students decide on educational opportunities outside the school; and student-curriculum brokers, to help students navigate the various curriculum options available to them.

Nickerson notes that even the role of a school librarian could change, as the library evolves from a place where books are kept to a "dynamic collection of learning resources." The librarian, then, is sort of a "learner-resource broker" whose function is to connect individuals to the complex resources that serve their educational objectives. Further, Fletcher states that, "Computer technology has from the beginning been used interactively to tailor the pace, content, difficulty, and sequencing of instructional material to the needs of individuals."[51] Thus, a computer could give individual instruction without needing a teacher present. How beneficial is the potential? Fletcher references three studies conducted by Bloom that found that students who worked with a private tutor saw a marked improvement in their scholastic performance. For example, he finds that a student who was in the 50th percentile could be improved to one in the 98th percentile after private tutoring. Of course, who is to say that individual independent learning on a computer would have the same effects as individual tutoring with a teacher.

CEO Forum

The CEO Forum defined four types of secondary schools by their technology integration: low tech, mid tech, high tech, and target tech. Target Tech schools (3% of all

[51] Fletcher, 2002

schools in 1997) strongly resemble Mastery Charter High School: class periods are longer and cover multiple subjects, promoting cross-curricular learning. Desks and workspaces may be arranged together in small groups rather than facing a blackboard. Teachers tend to be coaches and facilitators rather than lecturers. Students at Target Tech schools, the CEO Forum feels, will be more self-directed, and will have the opportunity to develop customized learning paths, better tailored to their interests and optimum work pace.

An open question is whether high school students are prepared for self-directed learning, however appropriate that may be for college-level study. Kay offers the example of Rio Salado Community College, which now offers 26 different enrollment periods using online technology, with a new class starting every two weeks. "This system helps adults whose schedules conflict with traditional academic calendars. Rio Salado now boasts higher retention rates and greater student satisfaction."[52] Adult students, of course, are vastly different from high school students.

I am not convinced the classroom layout has to change in order to incorporate computers. I suggest schools first find successful uses of technology, and expand from there.

Sivin-Kachala notes that "whether a given school experiences the potential benefits of technology depends on the software it chooses, what students actually do with the software and computer hardware, how educators structure and support technology-based learning and whether there is sufficient access to the technology."[53]

[52] Kay, 2003
[53] Sivin-Kachala, 2000

Scenario Planning

It is difficult to predict the future of educational technology. Schoemaker and Mavaddat recommend scenario planning techniques to help realize paradigm shifts in emerging technologies.[54] It is a valuable exercise to imagine various scenarios of classroom technology in the future – to imagine both the potential, (in order to map a course to reach that potential), and to anticipate unexpected outcomes that can occur. Most new innovations have these unintended outcomes – sometimes called "revenge facts." Cuban observed many expected and unexpected findings related to computers in the classroom, including:

"*Expected finding*: Students and teachers had access to computers and related technologies available in both their homes and their school.

Unexpected finding: Students and teachers showed little evidence of technophobia or resistance to using information technologies.

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

[54] Day; Schoemaker, 2000

week); between 20 and 30 were occasional users (once a month); well over half of the teachers were nonusers.

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 online 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.

Unexpected finding: There is no clear and substantial evidence of students increasing their academic achievement as a result of using information technologies.

Unexpected finding: The overwhelming majority of teachers employed the technology to sustain existing patterns of teaching, rather than to innovate.

Unexpected fining: Only a nominal percentage of high school and university teachers used the new technologies to accelerate student-centered and project-based teaching practices."

The main observation is that advocates of technology wanted *fundamental* change in the classroom, but teachers preferred *incremental* changes. Cuban compares this disparity by citing dynamics in other industries. For example, when engineers adopt technology, it is a different experience – a social, political, and organizational process.

How to scenario plan

Given these challenges to predict and plan for the future, Schoemaker recommends a set of steps to construct possible scenarios, which include:

- Identify stakeholders who will both be affected by the technology and be in a position to influence it;
- Define the relevant issues (time frame, scope, and decision variables) and determine the forces that will shape these issues (social, environmental, etc.) and their likelihood of occurring;
- Create and assess a plausible range of scenarios

The scenarios must be consistent (i.e., uncertainties that can coexist, and actions of stakeholders compatible with interests.) The final set of scenarios should be quantitatively mapped, and presented to others to enhance the decision-making.

Possible future outcomes for technology in secondary education

I apply scenario planning to computer-aided instruction. We have already outlined the stakeholders at the school: school boards, principals, teachers, parents and students. Other stakeholders who are affected and can influence the technology are: technology companies (both hardware and software), government bodies, and non-profit organizations involved in secondary education.

The incentives of technology companies are to:

- Profit from the technology applications;
- Build a relationship between the students and their applications that will endure as the students become adults and make their own technology investments;
- Garner positive PR through helping students
- Gain market intelligence to better understand customers' needs and preferences.

We see many technology companies interested in investing money into schools – both software (e.g. Microsoft) and hardware (e.g. Dell). These companies are highly motivated by the second reason: getting users on their systems early on for career-based applications (e.g. Excel). Focusing on this goal still accomplishes the other three goals. Given these incentives, technology companies have less of a need to see results in a short timeframe. Technology companies are not pushing hard enough to make the development investment in classroom-specific technology (e.g. computer-aided instruction). Schools and technology companies must partner together to develop the right technology solutions for students.

Government bodies are another stakeholder group affected by technology in secondary education. Their incentives can vary but are likely to include:

- Helping to ensure all populations have the same access to technology;
- Keeping the United States competitive with other countries;
- Using technology in ways that save schools money.

Thus, government bodies will make the necessary investment, but are more inclined toward cost-benefit analysis, and short-term results (before the next election).

Schools must naturally create their own timeline to see certain results or take a new direction. (The right timeframe is likely somewhere between the timeframe for a technology company and that for government bodies and ensures that all stakeholders buy into this timeframe.)

There are, of course, other outside forces that will affect any technology integration. Some questions to consider include:

- What role will technology play in the future? How do students need to prepare for this future? (Will this further motivate them to use technology in schools?)
- Will other countries also become important software providers, and thus, must we increase our scope of stakeholders?
- What will be the economic situation in the future? Will the United States continue to have the economic luxury to make investments without a need to see short-term successes?
- What are the criminal charges of students who hack into the computer systems? Could there be lawsuits because of students' personal information being uncovered by other students? Could this motivate schools to keep less information digital? Will security systems become more complex, but also much more expensive?

One possible scenario is that schools (either alone or in collaboration) first create a group to determine what goals and applications they want technology to accomplish. This board might very well include technology companies and nonprofit educational organizations to help broaden the playing field.

After schools have outlined what the technology requirements are, one possibility is for them to put out a request for bid to technology companies. The successful software bidder will complete the analysis phase and produce a beta product. This development path is well trodden. It has the advantage of setting expectations and milestones with the attendant accountability.

The plan developed should be one that satisfies all stakeholders, to ensure they will buy into it (e.g., affordable yet profitable, appropriate timeframe, etc.) The plan should also be one that considers outside forces. This consideration might simply be an understanding of the probability of the risks, and the decision that the plan going forward makes sense in light of these risks. Alternatively, the strategy might have contingency plans or options built into it if these forces occur.

Conclusion

Technology has become a part of our everyday lives, and educators recognize its potential for the classroom as an effective tool to help students learn. In 2001, 99 percent of US public schools had access to the Internet,[55] and 72 percent of classrooms had access to the Internet.[56] By 2002, the student-to-computer ratio reached 3.8 to 1.[57] Because of this wide availability, most students use computers daily. But teachers are still struggling to both become comfortable with the new technology and find effective applications.

Thus far, studies have shown that computer technology motivates students because it makes learning more fun and because students find computer skills valuable. That said, studies have not yet shown that students using computer-aided technology do better on standardized math or verbal tests.

We are still early into the Information Age. In order to reap real benefits of computer technology in the classroom, we need to first understand how it can best be

[55] CEO Forum on Education and Technology, 2001
[56] Nevens, 2001
[57] Staresina, 2003

applied and then develop the supporting software to translate that vision into reality. It is clear that the government should reduce the enormous investment in classroom technology and focus instead on a few carefully crafted pilot studies to determine what works best. Once those determinations are made, larger investments can be made strategically and more wisely.

The government is taking steps to ensure that underprivileged youth will not be left behind in the Information Age. By 2001, schools with more than 75% of students eligible for a reduced-price lunch had 79% of instructional rooms connected to the Internet and the student-to-computer ratio was 6.8:1.[58] Unfortunately, teachers in underprivileged schools are less prepared to apply technology towards high-level, abstract learning.

But where do we go from here? The government investment and approach to information technology is somewhat similar to investors' approach to the dot-com boom of the late 1990s. No one wanted to be left behind, and investors funded projects before fully understanding what the benefit would be. Although some projects were worthwhile, significant amounts of money were wasted. In the public education system, money is scarce and cannot be wasted. Scott Gordon, CEO of Mastery Charter High, advocates starting simple and cheap. This can be accomplished through used equipment and pilot programs. He also recommends close involvement with the administration to develop appropriate applications, rather than having all teachers experimenting on their own.

Schools can also take a proactive approach. They should carefully consider all relevant stakeholders and create a plan to reach their goals, while considering any

[58] Tabs, 2002

potential risks and outside forces. An important stakeholder group not to be overlooked is the software industry. They are in a position to develop the next generation of educational software and are positioned to bear a large part of the burden of developing high-level, abstract learning tools.

Schools have already made considerable investment in technology, and are learning for themselves what does and does not work. The road ahead is full of uncertainty, for both the school and the larger community. If technology is to be successfully integrated into secondary education, we must have both a keen awareness of past mistakes and a clear, specific, innovative, and pragmatic vision for the future. Above all, it will require patience.

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