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Computers Make Kids Smarter—Right?

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As money for technology pours into U.S. schools, policymakers, practitioners, and parents must wend their way through corporate ads, reformers' slogans, and academic studies in an attempt to answer this question: What should we spend the money on? The answer from current wisdom, which assumes that students profit mightily from new technology, is to spend it on computers. Two intrepid California educators, after a thorough survey of the best research available, aren't ready to go along with current wisdom.

Advocates for more use of technology in schools often say, "As the research shows. . ." But their assumption—that research shows that computers help schoolchildren smarten up—needs to be reassessed.

Over the past 30 years, studies of classroom use of computers have indeed found evidence of moderate effectiveness when it comes to the academic performance of students who use them. They also have found evidence of minimum effectiveness. And of no effectiveness at all.

Actually, effectiveness statements are of little use unless they elaborate the children's ages, the subject, the software used, the kinds of outcomes that were sought, and how the study was done. Few champions or skeptics of technology have much appetite for such details unless a particular study supports their views.

To answer the urgent question that many policymakers, practitioners, and parents ask—do students using computers learn more, faster, and better than if they were taught in familiar, nontechnological ways?—few of the interested parties have delved into the findings researchers have provided. Most have simply assumed that computers are effective and rushed to put new technologies into schools.

Questions
Although it is no longer a question of whether or not the nation will use computers in classrooms, there remain other important questions to which the interested parties need to seek answers. (Note that we use the terms *computers* and *technology* interchangeably.)

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 tools to create student-centered teaching and learning? To make our children more computer literate? And which software programs are best for English, math, and other subjects in the curricula of individual schools?
2. *Can we reach our goals at less cost—without additional investments in technology?*
3. *Will computers help create the type of students and citizens we seek?*
4. *Through what means can we achieve our desired ends?* In other words, what configuration of hardware, software, and Internet connections best meets our goals? Labs? Classrooms? Libraries? All of the above?

Here we will report on our recent reexamination of what researchers have said over the years about the effectiveness of computers. Then we may be able to determine whether the research provides any answers to those key questions.

Obstructions
In an ideal world, policymakers, practitioners, and parents who wanted to know whether technology was the boon to teachers and students that it claimed to be could simply read the research findings and come to an easy answer. Because it is an imperfect world, we should not be surprised that drawing clear conclusions from research is difficult.

The blurry picture stems mainly from a muddling of the aims for technology in schools. Three distinct purposes compete for resources. Policymakers and administrators seldom distinguish between calls for computers in the classroom for the sake of ensuring that students are computer literate, calls for computers in the classroom for more and better learning via computers (that is, acquiring academic content and basic skills, including higher-order thinking skills such as analysis and problem solving), and calls for computers to alter the classroom's social organization so as to make it more student-centered.

While it is clear that students will need to know how to manipulate databases, word processors, and other computer applications if they are to be competitive in the labor and undergraduate markets, what is less clear is how effective computers are as teaching tools or levers for transforming classroom organization. In coming to policy decisions about the best use of computers in schools, these distinct goals must be recognized and considered individually.

Learning
With the research that addresses the debate over whether or not computers help students learn math, history, English, and science, three features make it difficult to assess computer efficacy in classrooms.

First, research on the efficacy of technology in education is guilty of what education at large is guilty of: not having a clear focus. Some researchers measure effectiveness in terms of student scores, some in terms of how quickly students learn, and some in terms of how motivated students are to learn. The various outcomes desired by educators become the various outcomes measured by researchers.

Second, researchers study these different outcomes in many ways. We found studies whose samples varied in terms of student grade level, socioeconomic status, and aptitudes. Studies also varied by methodology. Some studies compared computer-using classes with non-computer-using classes; some simply reported on the outcomes of computer-using classes. Rarely has a study compared computer use with other educational options, such as peer tutoring and increased parental involvement. (See H. Levin et al., "Is CAI Cost Effective?" in *Phi Delta Kappan* 67 [1986], no. 10.) This means that the cost-effectiveness of computer use was seldom addressed. Each of these differences complicates any attempt to synthesize the study results and apply them to schools.

Third, studies of different types of computer use make different assumptions about teachers' roles in a computer-using classroom. For example, the majority of studies focused on computer-assisted instruction (CAI) and computer-managed instruction (CMI), both of which de-emphasize the teacher's role in helping students learn. Few studies focused on computer-enhanced instruction (CEI), in which the teacher is considered essential to the learning process. (See "CAI, CMI, CEI".)

Taken as a whole, these differences in the conduct of research can frustrate anyone who seeks to use the resulting studies to form any kind of conclusions, make easy comparisons, or create a simple synthesis.

With this advance warning about the complications involved, we offer our interpretations of the research findings. As there are three primary bodies of research on the efficacy of computers in the classroom, the next three sections of this article describe them: single studies, meta-analyses, and reviews criticizing both kinds of research.

Single Studies
Single studies, which make up a high percentage of the investigations, are the ones most often cited by both friends and foes of computer use in classrooms. These persons—rarely unbiased—thus have had a great impact on the way the research is interpreted.

Seven of the single studies of elementary and secondary school students yielded positive findings—ones that favored computer use in the classroom. The positive findings were seen most often in both achievement gains as measured by standardized test scores and indicators of improved attitude as measured by specially designed instruments. (See "Single Studies, Elementary and Secondary: Positive".) We found seven studies yielding negative or mixed findings that would give pause to practitioners and administrators rushing to use computers in classrooms. (See "Single Studies, Elementary and Secondary: Negative or Mixed".)

In general, there is little research on distance learning or technological applications for disabled students. The few studies that have been done—we found five—are positive and uncontested. (See "Single Studies, Disabled Learners: Positive".)

A plethora of reports on at-risk student use of technologies in classrooms boast positive results, but few rigorous studies have examined this population.

Ten studies on the effectiveness of computer applications in core curricula classrooms, including math, reading, science, and social studies, ranged from wildly enthusiastic to cautiously pessimistic. No other generalizations were clear from this body of the research literature. (See "Single Studies, Core Curricula: Mixed".)

> ***Scorecard***
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> When considering the single studies in general, what is striking is how few studies have policy relevance to the kinds of questions we asked and the prevalence of methodological flaws in many of the studies. *We can say on the basis of these single studies that the results for achievement and attitude improvement from computer use are mixed at best.* They provide a fragile basis for making policy or allocating resources for computers in classrooms.

Meta-Analyses
Researchers who do meta-analyses take the findings from single studies and calculate a way to compare them with each other. The goal is to synthesize the findings statistically and determine what the studies reveal when examined all together. Because meta-analyses include single studies that meet predetermined criteria, this method of analysis attempts to ensure that the results will be rigorous and carry more weight than dozens of single studies.

The major advantages of this approach are twofold: it resolves the problem of small sample size by pooling the findings of single studies to create a large sample size, and it addresses the problem of lack of a control group by rejecting all studies without control groups.

Typical criteria used in these meta-analyses required the studies to compare a computer-using class (experimental group) with a non-computer-using class (control group), be free from obviously crippling methodological flaws, and be available through primary libraries, such as the Educational Resources Information Center (ERIC) and Dissertation Abstracts. Ten meta-analyses done between 1977 and 1995 provided the bases for the findings we cite. (See "Meta-Analyses: Positive".)

While the analyses varied in their settings—primary, secondary, higher education—and in the number of studies they analyzed (from 16 to 254), each reported on student achievement outcomes. Half of the meta-analyses reported on efficiency of computer use (i.e., students learn more in less time), students' attitudes, and effectiveness by type of use (CAI, CMI, CEI). Differences by subject matter, age groups, and aptitude levels were inconclusive.

> ***Scorecard***
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> *Student achievement outcomes consistently favored the computer-using classrooms.* In other words, where students used computers in classrooms, scores were repeatedly and significantly higher than the scores of students in the non-computer-using classrooms. Percentage differences in scores ranged from 2 to 16 percentage points.
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> *For efficiency and student attitudes, the meta-analyses found that both were significantly improved in computer-using classes.* Students were able to learn more in less time and had slightly better attitudes toward computers, instruction, and subject matter.
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> Five of the meta-analyses (those preceded by asterisks) compared types of computer use: CAI, CMI, and CEI. They found that *CAI and CMI, in which teachers play a limited role in interacting with students, were more effective than CEI at raising achievement test scores in primary and secondary school classrooms.* But questions about the value of reducing the teacher's role are seldom asked by researchers, policymakers, or administrators who cite such studies to justify adopting and using new machines and software in classrooms.

Critical Reviews
Several researchers examined the single studies and the meta-analyses and found flaws. (See "Critical Reviews: Negative".)

Among their main criticisms were these: small sample size of the studies; lack of control groups; small effect sizes (that is, outcomes that were statistically significant but had limited practical impact); short duration of the studies; no control for teacher effects; lack of details on environment; and inappropriate achievement tests.

A frequent criticism voiced by authors of the meta-analyses was lack of controls for teacher influence. Both James Kulik and Richard Clark indicated that in studies where the same teacher taught the control group and the experimental group, the difference between the scores of students in the computer-using group and the scores of students in the non-computer-using group were not as great as when two different teachers taught the control and experimental groups. Thus, while teachers affect student learning, their effect is not controlled for in most studies of computer use.

Henry Becker criticizes the research for omitting details on the environment in which the computer-based learning was presumably successful. When studies neglect the details of the settings for experimental and control groups, Becker asserts, the effects of teacher training and experience and of classroom and school culture become entangled with the effects of the computer programs, thus confounding the results.

Becker also faults the studies for measuring achievement based on standardized tests, noting that achievement tests fail to measure accurately what the computer programs taught. When standardized test scores rise, it's difficult to discern whether the rise was due to the students' work with computers or another influence. Becker calls for tests that measure more precisely what particular software programs set out to teach.

Another concern with using achievement tests to measure effectiveness involves the matter of what skills they are measuring. Are standardized test gains a demonstration of computer software's ability to support students' short-term memory? Long-term memory? Or do the tests demonstrate software's ability to challenge students to think independently, creatively, and critically? Because such outcomes are difficult to quantify and other outcomes are far easier to measure, that which is easier tends to get assessed.

> ***Scorecard***
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> On the basis of the critical reviews, *we are unable to ascertain whether computers in classrooms have in fact been or will be the boon they have promised to be.*

Current Interpretations
While popular magazines, newspapers, and policy briefs typically publish articles that sing the praises of computers in schools and celebrate new purchases and computer applications, there has recently been a rise in the number of publications questioning the soundness of the costly move to equip schools with computers. (See "The Opposition".)

Among the considerable advantages of classroom computers commonly cited are systematically planned lessons, immediate feedback to students on their work, more individualized attention, improvement of student engagement and motivation, enhanced assessment, and access to enormous databases, spreadsheet programs, and graphics programs. (See "Computer Advantages".)

Among the considerable disadvantages commonly cited are that previous classroom technologies have failed time and again to meet public expectations, most software reaches for lower-order rather than higher-order thinking skills, and classroom technologies are severely limited in effectiveness if not set within a general reform context. (See "Computer Disadvantages".)

Magazines, newspapers, and policy briefs are selective in which studies they cite; sometimes they ignore research findings entirely. When popular publications champion computers in the classroom, they ignore the fact that research findings are mixed. When skeptics voice concerns over schools' passions for computers because student learning of content matter is unsupported by the research, their arguments are not always heard, since distinctions between the reasons for using computers are often blurred, as we noted earlier. Distinctions among goals are seldom made in the debate over the values and uses of computers in the classrooms.

If policymakers, practitioners, and parents were to keep their eyes focused on what is known and talk within the boundaries of reasonable generalizations, and if all players could agree on the purposes of computers in the schools, perhaps the overheated debate might de-escalate.

If researchers could inquire into the common advantages and disadvantages popularly attributed to classroom use of technologies, then publish their findings while engaging in public discussions, the hype and phobia that accompany most policy debates over computers in schools might dissolve.

But we recognize that those are very large *if*s, and in that spirit we offer our closing observations and answers.

Observations
The answer for policymakers, practitioners, and parents who ask "What can we learn from the research?" is complicated. It depends on what their goal is and on how, when, and where the research was done.

Working from what we know about the effectiveness of computers in classrooms, the following pathways are open to schools.

We know that CAI and CMI have been shown to improve standardized test scores. These findings, however, are considered methodologically flawed. Moreover, hardware and software changes occur far faster than researchers can study them. Changes in computer speed, memory, and programs make earlier studies virtually obsolete.

With these caveats, schools can accept, conditionally accept, or reject the positive research findings. Accepting them, even conditionally, would imply the need for increasing use of CAI and CMI applications only. Rejecting them would imply the need to minimize or eliminate use of CAI and CMI.

If a school staff decides that raising test scores is a desired outcome and accepts the research findings, increased use of CAI and CMI would follow.

If a school decides it is more interested in applying technology to student-centered teaching and learning, the staff would look to models of schools that have used CEI to support this direction, because the evidence that CEI is effective is based upon single models with specific organizational structures and pedagogical methods. (See "CEI Models".)

If a school decides to apply technology to support another type of reform, such as aligning goals, curriculum, and teaching approaches to raise reading and math standardized test scores, the school could look to models of schools using similar technologies and reforms. These models will be replicable only insofar as districts and schools organizationally make it possible for teachers to create sound curricula that integrate technology consistent with the aims of the models.

Note, however, that using computers beyond CAI and CMI applications means that teachers become critical elements in applying CEI. Thus in advocating the use of computers for more than improving standardized achievement scores, policymakers and administrators will find themselves facing the familiar conundrum in the history of school reform: teachers as both the problem and the solution. Teachers are designated as the problem that CAI and CMI address by more efficiently improving standardized test scores through individualized computer drills. Yet CEI, which is becoming more popular, requires teachers to play a far larger role in interactions between students and machines.

Are teachers both the problem and the solution? This is not a playful question. We stress that policymakers, practitioners, and parents need to know what they want to achieve with technologies, be familiar with research findings on CAI, CMI, and CEI, and connect their aims to what is known.

> **CAI, CMI, CEI**
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> - **CAI** (computer-assisted instruction) refers to computer programs that provide students with drill-and-practice exercises or tutorial programs.
> - **CMI** (computer-managed instruction) refers to programs that evaluate and diagnose students' needs, guide them through the next step in their learning, and record their progress for teacher use.
>   Both CAI and CMI de-emphasize the role of the teacher in tending to student learning.
> - **CEI** (computer-enhanced instruction) differs from CAI and CMI most noticeably in that its programs provide less structured, more open-ended opportunities that support a particular lesson or unit plan. Use of the Internet, word processing, and graphing and drawing programs are examples of CEI. Teachers in CEI are viewed as essential to the learning process, because simply seating students in front of their computers to surf the Net will not result in the same learning curve as when teachers assign well-designed projects in which students use the Net to gather information.

Questions—with Answers
On the basis of this review of the research, how would we answer the questions posed at the beginning of this article?

1. *What do we want to use computers for in our classrooms?* Researchers cannot answer questions of purpose; policymakers, practitioners, and parents must and should consider the questions for themselves and determine their aims.
2. *Can we reach our goals at less cost—without additional investments in technology?* Too few studies have examined the cost-effectiveness of computers to judge whether alternatives to computers can secure the same results.
3. *Will computers help create the type of students and citizens we seek?* Prior research is of no use in answering such questions, because what is needed is an evaluation of the fit between the existing mission of the school and how technology is used.
4. *Through what means can we achieve our desired ends?* The answers found in the research are either inconclusive or indeterminable.

The Role of Research
Let's not kid ourselves, however. Even if policymakers, practitioners, and parents did decide what their goals were and even if the research findings supported one of several configurations of hardware and software, deciding when, how, or if to use technology (or any other reform) in the classroom is not likely to be determined solely on these bases. Many other factors—ranging from parental pressure to superintendents wanting to leave their fingerprints on the district to technology corporations promoting their products—shape decisions to buy and allocate technologies to schools.

Given these pressures, it is that much more imperative that educators have a clear sense of their goals for technology and that researchers focus accordingly. What can be reasonably concluded from what is known (and not known) about computer use in classrooms should, at the minimum, be put on the table for policymakers, practitioners, and parents—along with other interested advocates and skeptics—to use in their deliberations.

After all, the more we understand about what it takes to create a more perfect world, the closer we may come to it.

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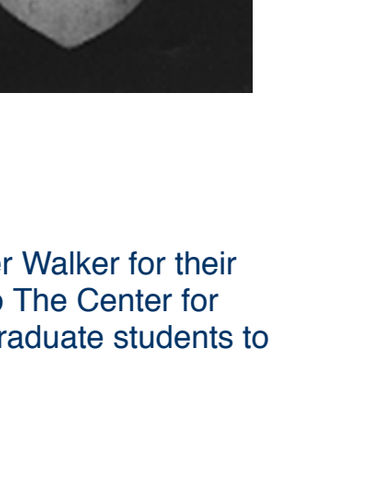

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