CENTER FOR ASSESSMENT AND POLICY DEVELOPMENT

CAPD

INVESTING IN COMPUTER-ASSISTED LEARNING: A BRIEFING PAPER PREPARED FOR THE CHARLES STEWART MOTT FOUNDATION

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MARCH 2001

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I.INTRODUCTION & SUMMARY OF FINDINGS

Just as people once predicted, computers have become part of our daily lives as we begin the 21st century. Market-driven applications abound for commerce, information exchange and recreation, and the price of entry to the technological revolution is dropping for businesses and families. But our futuristic visions to transform education via technology are still largely unrealized. Schools have computers but they are often not well used; cognitive theory and technology are each advancing rapidly but often not together; the majority of kids who struggle via traditional pedagogy are not yet connected to applications that make complex material simpler to learn or that bypass barriers related to processing written language, hearing, vision, fine motor skills, etc. Whatever the forces — pedagogical, economic, political — that would infuse technology into education, they are not yet sufficient to get the job done.

This document is intended to serve as a briefing paper for the Charles Stewart Mott Foundation on the current status of computer-assisted learning, a term we are using to mean the infusion of computers and related technology into education for the purpose of improving student outcomes. Computer assisted learning is not generally the sole source of instruction; unless otherwise stated, it is a strategy to supplement a classroom teacher. The Charles Stewart Mott Foundation commissioned the Center for Assessment and Policy Development (CAPD) to review computer-assisted learning as a potential area of investment.

This briefing paper focuses on whether or not this technology holds specific and special promise for students who are considered to be at-risk of poor academic outcomes. By at-risk, we mean students who are performing below grade level on standardized tests in middle or high school, or who are currently attending alternative schools primarily because they were not successful in more traditional classroom settings. Because of this, these students are often at risk of being excluded from learning approaches or topics that nurture higher order skills and lead to more advanced opportunities. Many of these students are also at-risk of not staying in school through graduation because of the time it would take for them to catch up and succeed.[1]

Given this focus, we originally intended to organize information by categories of risk factors for students, e.g., by reading levels, progress toward a high school diploma, whether or not a student was in an alternative setting or not, etc. However, we did not find a great deal of literature or practice about computer-assisted learning organized in this fashion. This is because part of the promise of computer-assisted learning is the capacity to provide material to students that is very individualized to their particular learning styles and curricular goals. Computer-assisted learning also appears to be very useful in terms of making complex material simpler. For both these reasons, technology can work for students at a wide range of reading levels and/or those who are at varied stages on a path to high school completion.

In many ways computer-assisted learning appears to hold promise as an equalizer, making traditional risk categories inappropriate. Thus, organizing what is known by traditional risk classifications is not particularly helpful. This probably comes as especially good news to the many teachers, parents, students and others in the field who oppose tracking, isolated drop-out prevention programs or other educational strategies that rely on, and reinforce, student labeling.

To prepare this briefing paper, CAPD reviewed research about the effectiveness of computer-assisted learning at improving specific educational outcomes, including several meta-analyses and program and initiative evaluations. We also reviewed several best practice compendiums or syntheses. There is a vast body of literature and work in the general field of education and technology. It was outside the scope of this project to review all of it. However, there are a number of very recent compendiums and reports that themselves contain very current scans of research and best practices. We particularly want to mention

Children and Computer Technology, which is the fall/winter 2000 issue of the Future of Children, a publication of the Packard Foundation. It contains several well-researched articles that reviewed many of the same topics we investigated, and reached very similar conclusions. It is an excellent source of more detail and many specific examples for several topics that can only be touched upon in this briefing paper.

To supplement this information, we also interviewed fifteen national experts who are involved in the education of at-risk students in a variety of ways (see Table 1). Information from these interviews substantially informs the briefing paper. Thus, while the paper is not organized around categories of risk, special issues are highlighted as they arise.

The remainder of this paper highlights some of the key insights and findings from the field, and lays out some potential areas of investment. Our basic conclusions are:

- Many observers and educational experts believe that computer-assisted learning is worth pursuing. This is because the things that it can provide — individualized teaching, access to 'higher level' content by making complex material easier to master, connections to a broad array of learning options, infinite patience — align so closely with good pedagogy and the opportunities that educators have wanted to provide their students for a long time. In addition,
    - While existing research is not definitive about the effects of computer-assisted learning on educational outcomes, there are a number of promising findings; and
    - Experts (and parents) believe that schools should ensure that students master computer and related technology, whether or not there is a direct benefit to educational outcomes. They believe students must have these skills to succeed in post-secondary training and education, and to be employable in the twenty-first century.
- There are enormous variations in the extent to which computers and related technology are infused into education. For example, there are several schools and programs in which technology is thoroughly infused into all aspects of the work — for curriculum, course offerings, assessment, research, administration and communication. There are also many examples of schools and programs at the other extreme. These are the places that own just a few computers, often used mainly for administrative tasks. Experts with whom we spoke said the most typical pattern is toward the lower end of this range. According to them, the majority of high schools, community-based programs, corps and alternative schools own some computers, but not enough for each classroom or every student. Teachers and programs are experimenting with educational applications but technology is not infused in everyone's thinking or curriculum; computers are marginal and not fully integrated with learning.
- Not surprisingly, students who attend schools with limited financial resources have much more limited access to computer-assisted learning than students who attend more affluent ones. Even though the cost of basic computer access is dropping, the 'digital divide' between rich and poor programs, neighborhoods and school districts remains substantial. The cause seems to be linked to school financing based on local property value that creates resource disparities. Because of this, it will be important to equalize access to, and the likelihood of benefits from, technology among different groups of students using policy and market-driven solutions.
- Knowledge to share or replicate good models also varies substantially across academic disciplines and particular uses or goals. For example, there is much more research about how best to use technology to improve math and science learning than about how best to use technology for competency-based learning

that allows students to accumulate credits toward graduation rapidly in a fashion not tied to time in a seat.

- There are several useful clearinghouses and sources of expertise nationally (from groups working on school reform, alternative educational programs, the small schools movement, etc.) and in a few states (Georgia, for example). Given the state of the art, however, even very good sources cannot always provide the detailed and specific information practitioners need to match an application to a curricular goal or to adopt a new practice. The consensus of the experts to whom we spoke is that individual teachers who are very motivated to find curriculum, applications, research and replication material can often track it down, but it is not easy.

- The field does not yet know the precise or full range of conditions for computer-assisted learning to achieve maximum impact.

    - It is not possible yet to know what it might cost in money and effort to take computer-assisted learning "to scale," if that is warranted — that is, for it to be available to every student nationally who would benefit.

    - At the same time, there is a consistent and growing body of research and practice about the kinds of conditions that need to be in place, including, but not limited to, things like teacher development, easy access to appropriate knowledge, educational vision or leadership open to technology, enough computers for each student, technical support for installation and maintenance, and money.

Given all this, one can make a strong argument for investing in upgrading the capacity of schools and alternative programs to acquire, maintain and make maximum use of computer-assisted learning to support better student outcomes. No one essential next step emerged from our review, and there is more to do in this field than any one funder, or even a broad coalition of funders, could tackle all at once. In terms of investments, the field is such that there are multiple opportunities among which investors might choose.

The remainder of the briefing paper is organized into the following sections:

- Chapter II summarizes very briefly research on the effectiveness of computer-assisted learning at improving student outcomes;

- Chapter III reviews the implementation of computer-assisted learning, in terms of uses, barriers and conditions that promote computer-assisted learning; and

- Chapter IV suggests several potential areas for investment.

We hope this information is helpful to the Charles Stewart Mott Foundation and others, and welcome further discussions, comments and questions.

II. SUMMARY OF EFFECTIVENESS

There have been several recent efforts to assess the effects of using computers and other technology to improve academic outcomes for youth. They include meta-analyses of studies assessing the effectiveness of computer-assisted strategies to improve academic performance, evaluations of major initiatives, reviews of recent research and reports of individual research findings. Outcomes that have been measured include, but are not limited to, improvements in standardized test scores, improvements in school grades in particular subjects and acquisition of particular skills or concepts. It is difficult to summarize findings with precision across these multiple sources because findings are based on different applications, in varied settings, using different tests of effectiveness.

Given the diversity of types of computer-assisted strategies employed and the relative dearth of traditional summative evaluations, it is difficult to draw conclusions about the effectiveness of all of the different types of computer-assisted strategies, or even the most common. Nevertheless, the research does allow us to draw conclusions about effectiveness at the level at which investment decisions typically must be made (i.e., is it reasonable to invest in computer-assisted instruction; what types of benefits have been observed; what types of supports must be in place to increase the likelihood of effectiveness; etc?). This chapter presents findings at this "big picture" level, with some additional detail in Appendix A. Readers should keep in mind that findings at this level will inevitably gloss over or obscure distinctions that are important to researchers and practitioners.

Major findings are summarized below:

- Findings are clearly mixed; some studies show effects of computer-assisted learning on educational outcomes and some do not. Findings are inconsistent even across relatively comparable studies (that is, based on similar software and/or population).

- The most recent meta-analyses are promising, in that, while there are studies indicating significant and non-significant differences, more of these studies show positive findings than show negative or no effects. That is, results of published and unpublished studies in four recent meta-analyses (12, 23, 37, 47) show positive results for academic outcomes (e.g., amount of information learned initially, amount of information retained over time, time needed to learn lessons, course completion rates, post-test scores) more often than not when computer-assisted learning is employed.

- Several studies indicate that computer-assisted learning promotes analysis, generalization of concepts from a classroom instructional example to real world applications, logical and scientific reasoning and other tasks typically considered "higher order thinking skills" (12, 23, 37, 47). For example, some studies show that math computer applications that promote reasoning improve math scores on standardized tests while ones using drill methods decrease math test scores (36). Computer-assisted learning seems to be particularly effective when it is being used to break complex ideas into simpler ones (12, 23, 37, 47).

- One meta-analysis, by Fletcher-Flinn and Gravatt (12), found that computer-assisted learning does not produce significant learning benefits compared to traditional instruction when the same materials are used, but does produce benefits when materials are different. This finding is consistent with what the experts we interviewed told us — that it is not a computer per se that matters for students, but rather its capacity to provide content via materials that can be interactive, multi-dimensional, multi-media, disaggregated, reassembled, etc.

  Experts believe that findings will be more consistently positive as applications improve. By applications, they mean the combination of technological delivery system (e.g., software, web access, real time virtual classrooms), subject or content (e.g., arithmetic, calculus, critical reasoning across multiple subjects) and instructional method (automated three dimensional charts, text, links to real world examples).

- Another key finding, consistent across meta-analyses, is that the effectiveness of computer-assisted learning is significantly influenced by the amount of training teachers received to use the particular application being studied (12, 23, 37, 47). Experts also take the position that the extent to which teachers are trained to use technology greatly affects its effectiveness.

  This certainly makes intuitive sense. But it is also important to note that, at the level of meta-analysis, it is likely that "teacher training" is a proxy for many things, including: meaningful integration of computer-assisted learning with curricular goals, increased opportunities for students to work on computers, ongoing technical assistance for teachers to use computer technology, availability of research and ideas for teachers to use computers and appropriate computer applications, support for teacher use of computers by school leaders and sufficient funding for meaningful integration of computer-assisted learning into the daily life of a school or alternative program. All of these things have been cited as important in reviews of computer-assisted learning, though they have not typically been separate variables in meta-analyses or outcome research.

- There are a number of reasons aside from the value of computer-assisted learning per se why findings may be mixed. One may be variation in the quality of available applications, as noted above. Another may be variation in the quality of implementation of computer-assisted learning in a given setting, as discussed more fully under barriers and conditions, below.

Some reviews have isolated findings for at-risk students, often while reviewing benefits for special education students.[2] They find positive results for at-risk students using computer learning applications that:

- Teach writing to students at risk of academic failure (25). For example, the "attributes of word processing that lead to its effectiveness as a learning tool for children with special needs are generally the same attributes that make it effective for children in general. For example, the ease of revising text, producing clean and readable text, and feeling a sense of authorship are frequently mentioned as attributes of word processing that lead to improved writing" ([18] Hasselbring and Williams, 106–107).

- "Allow students to share reasoning with other students, provide on-the-spot diagnoses and correct faulty reasoning at every step." "Changing How and What Children Learn in School with Computer Based Technologies" cites two studies, a 1997 study by Koedinger, Anderson and Hadley and a 1999 study by Bransford, Brown and Cocking, that demonstrate that these types of applications may show small or no gains on standardized tests for all students, but big gains for students defined as at-risk of school failure (36).

- Use constructivism to help students master complex subjects through a series of simpler steps, and does it in such a way that students can apply what they are learning to other situations and settings. Constructivism refers to learning methods in which students actively build information or understanding from their own inquiries. Support for 'project-based learning' or 'student-centered learning' are based on a belief in constructivism as an effective cognitive process.

What can be taken away from these findings? They tell a complicated story. On the one hand, currently-available data do not show consistently positive effects. On the other hand, the benefits that are produced are very important. Computer-assisted learning makes complex material simpler and more accessible to a greater proportion of students. This opens the door for many more students to take on many more subjects, and allows students struggling with basic skills to practice higher order and more complex tasks earlier and more easily. In addition, computer-assisted learning provides a floor of teaching not wholly dependent on what a given teacher knows and can teach. These benefits have heretofore been very hard to provide at scale for large numbers of students. They are also very consistent with what people believe are essential elements of good education.[3]

Available evidence may also understate considerably the potential for computer-assisted learning to improve student outcomes. Taken together, this body of evidence indicates:

- Not every form of computer-assisted learning provides benefits to every student — the effectiveness of computer based strategies is determined in part by the fit between student needs and software design;

- Research on several in-school technology projects suggests there are some necessary conditions and changes that lead to improved outcomes for students who are performing poorly academically. They include things like immediate and ongoing support for integration of technology, support for educators to plan carefully and implement learning activities using technology, and help to shift to project-based learning and peer support.

- Review of best practices for out-of-school youth also suggests some necessary conditions and changes for computer-assisted learning to be of maximal use. They include things like providing access to dedicated computer equipment and supports in non-traditional settings, providing teachers who know how to support students working on self-paced computer lessons or programs and creating flexible contracts between schools and students with defined expectations.

Since widespread use of computer-assisted learning is relatively new (since the mid 1980s), and changing rapidly, many of these hypotheses are untested. Evidence currently available often comes from less than optimal situations. Thus, it would not be surprising if greater use and further research shows consistently more positive effects over time.

III. POSSIBLE USES, BARRIERS AND NECESSARY CONDITIONS TO ENSURE IMPACT

Computers have several properties that support their being used in multiple ways. They store, sort and produce information that schools and programs can use for pedagogical or administrative purposes. They offer connectivity, which can aid communication among students or among faculty, between students and faculty, parents and schools, or students in one location and information or people in another. They can be tailored in many ways to the needs or interests of a particular student or other user, so they can support individualized education strategies such as competency-based learning, rapid accumulation of high school credits or GED study. This same property is why computers can also be used as assistive or adaptive devices that can remove or ameliorate visual, auditory, orthopedic, neurological and some behavioral barriers to learning. And, because they are machines and not human, they can do repetitive or complex tasks 24 hours a day, seven days a week, which makes them particularly able to support learning outside of traditional hours and settings. Finally, computers are products and business tools, so learning how to use, design, build, repair, market, recycle and/or dispose of them are potentially valuable vocational skills.

Thus, there are a myriad of ways that computers can be used in school settings. This section of the briefing paper lays out a typology of uses, describes some barriers to implementation or expanded use and then discusses what appears to be a minimum set of ideal conditions that have to be in place for schools or programs to get maximum use from their investment in computer technology.

Ways in which computers are used to support educational goals

The kinds of uses that came up most often in our review and in discussions with experts are:

- **To help students achieve core curricular goals (e.g., to teach basic skills, as the platform for science or math instruction, as a major means by which teachers help students master a particular competency).** For example, by fostering and serving as a vehicle for project-based learning; supporting mastery of complex subjects; supporting acquisition of basic skills; providing alternatives to standardized tests for assessing student or school performance, etc.

- **To expand course offerings** (via distance learning and Internet classes). For example, schools and programs readily think of using distance learning or Internet classes to teach advanced placement or language classes to high performing students.

- **For enrichment, that is, to augment student experiences but not as the basic method by which something is learned** (e.g., by connecting students to other classes and to national and international experts, cultural exchanges, on-line scientific experiments and other resources, and by the engaging nature of the technology itself for many students). For example, many teachers permit students to go on the Internet to find out more about a topic once they have read about it in their textbooks or heard the teacher's lecture, but they may not think to use the Internet as the primary teaching tool.

- **To help students obtain high school credentials** by serving as a vehicle to accumulate high school credits quickly and/or get a GED (not tied to time in seat);

- **To enable students with learning disabilities and physical challenges to process and produce information** more effectively. (Information related to these uses is captured in documents like *Technologies for Remediation and Compensation of Learning Disabilities* (15);

- To **teach basic computer/technology proficiency** (e.g., word processing, data base management, web access and Internet search). There is some effort in the field now to create competencies and standards about the teaching of these proficiencies;[4]

- **To support acquisition of a very broad array of advanced technological and/or vocational skills** (e.g., computer repair and design, computer graphics and animation, music mixing and production, automotive diagnostics, rocket design, oceanographic research, etc.); and

- **To serve as a management or administrative tool**. For example, computers are often used to manage student data bases, budgets and scheduling. They can also be used to help counselors, employers, teachers and students coordinate a student's learning more effectively via Internet conferences and feedback, though this happens less frequently.

Table 2 contains some information about the use of computers to support each of these goals, including examples, potential benefits and barriers to implementation. The table highlights several key points:

- There are working examples of how computers can be used to support each of these activities;

- At the same time, the quantity of available information varies substantially across areas. For example, there are a number of applications people know about to support basic classroom pedagogy, enrichment and to expand course offerings.

  There are some examples people know about to teach basic and more advanced computer skills. There are many examples from outside education about how to use computers for management and administrative purposes, but few tailored to the specific needs of schools or alternative programs. Finally, there are many applications to support GED acquisition (in part because of Job Corps' use of computerized learning for many years), but not very many to support rapid accumulation of credits toward a high school diploma not tied to time spent in seat. This is an important distinction since the long-term benefits of acquiring a GED are substantially lower that those from acquiring a regular high school diploma from an accredited high school.

- The same computers can support many uses, and those could provide multiple simultaneous benefits. For example, students with access to computers and appropriate applications in schools can simultaneously: do better in school; learn for themselves unbounded by their particular school or any other place-based boundaries; and master basic and sophisticated vocational tools.

- There are frequent barriers to implementation, discussed more fully below. They range from issues related to installing and maintaining computer equipment, to people knowing how to use them to accomplish particular ends, to having enough computers so they can be fully utilized in multiple, simultaneous ways, thus reducing the potential ratio of costs to benefits.

The use of computers to improve outcomes for at-risk and academically challenged students

As noted earlier, we talked to a number of practitioners who are working on improving educational outcomes for adolescents and young adults and who are using computer-assisted learning as a tool to achieve those ends. As indicated in Table 1, they include people involved in the small schools movement, reform of urban comprehensive high schools and technical assistance to service and conservation corps, and Job Corps. They also include people running highly wired high schools, alternative schools and corps. They were very helpful in identifying many of the uses described above, observed and potential benefits and implementation barriers.

These experts made several additional points about the use of computer-assisted learning to support better outcomes for students, particularly at-risk students. They asserted that:

- Computers are not essential to improving educational outcomes for students, but they can make it easier to deliver effective instruction. For example,
    - Students master subjects better when they can: control and organize new information themselves; work through multiple examples of a new concept in ways that reinforce whatever particular issue they are struggling with; and get rapid and specific feedback. A good teacher can create these conditions and provide this kind of support to a student, but it is very hard for even a master teacher to deliver this level of quality support to many students simultaneously in a time-limited interaction every time they meet. But good teachers can write applications that meet these needs, and use computers to support their delivery to many students at a time.
    - Computers used for management and administrative purposes free-up teachers' and administrators' time and give them better ways to communicate. Lack of preparation and meeting time has been a major barrier to creating teaching communities of the kind espoused in the small schools movement; people in this movement see the benefits of computers for reducing this barrier.
- Computers are not being used in many places to accomplish all or many of these things. For example, one expert, talking about the penetration of computer-assisted learning into comprehensive public high schools, suggested most schools with whom he works do not have enough computers for most students to have access to them in most of their classes. Another, talking about service and conservation corps, indicated that nearly all corps have computers — but their use ranges widely. He believes "wired" corps in which computers are fully integrated into employment, vocational, educational and administrative components (e.g., the Los Angeles Conservation Corps) are the exception. The more typical case is a few computers in the building not used for multiple purposes, that is, used solely for administrative, GED preparation, or vocational training.

Experts also believe that the more schools and other educational programs experiment with multiple uses for the same equipment, the more they will want to expand their use even further. One reason is because people will become much more facile with the equipment and applications, and will, therefore, be much more comfortable seeking out and creating their own new uses. Another is that people will begin to realize the multiple simultaneous benefits described above, so they will begin to believe there is a pay-off for the effort required to adopt a new way of doing their jobs.

Most of the experts with whom we spoke believe that computer-assisted learning is being vastly underutilized given its potential. They also suggested several barriers to expanded use of computer-assisted learning, discussed below.

Barriers to expanded use of computer-assisted learning

It is reasonable to ask why we are not implementing computer-assisted learning to support education now, as a nation or at individual schools or programs. The answer is complicated, both because of a lack of empirical data that defines likely results, and because implementation of computer-assisted learning faces barriers simultaneously from at least three directions, each of which might be sufficient to stymie implementation on its own. These directions include, at least:

- Typical barriers confronting the adoption of any major new technology that changes how people interact and spend their days (e.g., like those accompanying the introduction of the assembly line, telephones and television);
- Resistance to change within educational systems and among practitioners trained in other ways of working; and
- Challenges associated with the distribution or redistribution of public and private resources.

Each of these phenomenons has spawned its own theoretical and practical body of issues and solutions, which are useful to keep in mind when thinking about investments related to implementation. Some of what we learned about how these factors relate directly to implementation of computer-assisted learning, particularly for students at highest risk for poor educational outcomes, is summarized below.

- Policy makers and other flinders are generally aware that there are substantial costs involved in "wiring" a school or program — that is, to bring in hardware and software, to pay for an Internet connection, etc. However, people are not always aware of the full range of labor and out-of-pocket costs involved. These costs typically fall into two categories:
    - Costs related to installing and maintaining the equipment. Hidden, but very substantial, costs of these kinds include: costs for updating the electrical capacity of an older building to support computers; the costs for having an adequate supply of computers to allow meaningful access (some recommend full access in all classes for all students); costs to purchase and properly license software; costs to update, repair and troubleshoot when necessary the hardware and software; costs to research and/or adopt applications to meet state or school specific curricular goals. These costs are generally born by a school district, school or program, though some may be off-loaded to parents (e.g., by asking or requiring students to do much of their homework on computers thus pressuring the family to buy computers for their students' use).
    - Costs related to building the capacity of people to use the equipment well. These costs include teacher development, training and support to integrate computers fully into instruction at all levels. These costs are often shared among colleges that train teachers, states (e.g., as in Georgia which runs statewide technology training programs), schools or programs and teachers themselves.
- Inadequate resources and inequitable access to computers are tightly linked:

Investing in Computer-Assisted Learning (cont)

- For example, Sheilds and Behrman cite NCES data that indicate “only 39% of the instructional classrooms in lower-income schools have Internet access, with a ratio of 16 students per computer. In contrast, some 74% of instructional classrooms in higher-income classrooms are connected, with a ratio of seven students per computer” ([41]) Sheilds and Behrman, 16).

- Schools in poor communities are also much more likely to have computers that are more than five years old. Older computers often have inadequate capacity to run the most recent computer applications. However, more recent applications are the ones most likely to build on current science about cognition and learning, and thus, to produce more consistently positive results.

People are working on solutions to these barriers at multiple levels. For example, the federal government and several states, in partnership with foundations, are working on ways to help all schools in a state have a basic floor of equipment, software and training. There are also efforts to reduce the costs of Internet access (through e-rates); and to build economies of scale into training (through state technology academies).

- Conscious or unconscious teacher resistance is also a major barrier to full implementation of computer-assisted learning. People articulate the nature of this resistance in different ways, each of which suggests different remedies.

  - Some people believe the resistance is generational — older teachers unfamiliar with the technology naturally resist it, and resistance will fade as younger teachers replace older ones. Solutions call for changes in how educational colleges and other institutions train student teachers, establishment of standards for technological use, which will change teacher practice and massive retraining of current teachers. The federal government and several states are investing in these kinds of solutions, as are foundations.

  - Another perspective is that teachers (and administrators) are resisting yet another educational fad which has not yet proved its worth. People making this argument cite mixed evidence of effectiveness, lack of research tied to their particular settings and/or curricular goals, and lack of research comparing costs to benefits for large groups of students, e.g., for whole school districts or communities. Solutions hinge on creating the necessary conditions to maximize benefits and research to document the results, and on research that helps teachers choose applications that work to meet their particular curricular or pedagogical goals.

  - While acknowledging both of these issues, some people also believe the resistance lies in power dynamics between students and teachers, where teachers gain power by controlling information, that is, by being “the expert.” Computers threaten this role in many ways — by providing avenues to information no single teacher could possess, by encouraging students to manage their own learning; and by connecting students more with each other and people outside the classroom. People concerned about these issues often point to solutions that involve personal transformation of teachers to see themselves differently and/or peer support to help individual teachers manage the discomfort that accompanies a change in their roles.

- Lack of necessary information is also a barrier to fuller implementation of computer-assisted learning. While there is a great deal of information about computers and schools (more than could be incorporated into this review for example), there appear to be some significant gaps.

- There is a dearth of readily accessible and practical information to help practitioners sort among myriad applications. Such information would tell people which particular applications produce certain kinds of benefits (e.g., raise reading scores for students reading below various grade levels); provide information about how to use them in particular settings, link applications directly to curricular goals or standards, etc.

- Information is also uneven across the eight categories of use described in the previous section. For example, while there is a great deal of information about classroom applications to support improved math and science skills, there is very little about using computers to support self-directed learning for rapid credit accumulation by removing time-in-seat constraints. This is a particularly serious issue for those who want to support students not doing well in traditional settings.

- At the same time, there are several established clearinghouses that can provide some of this information, and more are being developed (e.g., Southern Regional Education Board (SREB), www.sreb.org, Computer Assisted Language Instruction Consortium CALICO, http://calico.org, and ERIC Clearinghouse on Information and Technology, http://ericir.syr.edu/ithome). The state of the art is such that highly motivated teachers, administrators and other practitioners probably can find much of the necessary information to guide decisions and daily practice. However, it takes a certain level of technological fluency and interest to get to this information, and to use it well. So the channels by which information is being disseminated (e.g., Internet access, academic literature, regional or topic-specific clearinghouses) remain a barrier for many.

These barriers cross all spheres and communities, but are particularly troublesome for at-risk students. The reasons are highly related. First, solutions are not free — they call for investments in equipment, their maintenance and upgrading, development of applications, training — which are usually hardest to come by for students in poor school districts with large proportions of poorly performing students. Second, there is little evidence to date that market forces alone will equalize access to high quality computer-assisted learning, and the country remains deeply divided on how to redistribute educational resources more fairly through policy, rather than or in addition to, market forces. Third — because they lack a strong constituency and resources — applications or the knowledge gathering and dissemination around uses of the most pertinence to at-risk students are not developed. Fourth, research has not yet defined the most cost-effective way to obtain benefits from computer-assisted learning, though there is some early evidence to begin this work. The next section of this chapter takes up this latter issue in more depth.

Ideal conditions to foster computer-assisted learning

No one yet has determined the minimum set of conditions that need to be in place in order for computer-assisted learning to realize its full potential; in current language, a “theory of practice.” This information would be important for several reasons: to give practitioners a kind of minimal checklist for implementation; to establish likely costs; and/or to identify a floor of conditions that should be in place before one tries to measure benefits. We believe it is also a necessary underpinning to begin to think about things that would need to be supported through investments to the field.

While we did not uncover a theory of practice per se, we did review findings in the effectiveness literature with respect to the context and conditions associated with better outcomes, as noted earlier. This analysis helped us put together a list of necessary conditions for success. Not surprisingly, these are consistent with the critical barriers mentioned by the experts whom we interviewed, hypotheses and conclusions of several published experts and with theories of diffusion of innovation and educational reform. Thus, while unproven, they represent current thinking in the field.

We posit, therefore, that the following elements represent a minimum threshold of things that need to be in place for computer-assisted learning to take hold and be effective:

- Leadership around technology and education (e.g., from a principal or program director, board member, governor, etc.). Leadership must include:
  - Vision about what's possible; and
  - Willingness to find the resources to fund all of the necessary costs at an adequate level.
- Basic technology infrastructure, including:
  - Wiring and other structural changes related to the capacity of buildings to accommodate sophisticated hardware;
  - Hardware; and
  - Regular maintenance, trouble-shooting, upgrading of equipment and/or building capacity for teachers, students and administrators to do these things.
- Useful and readily useable information, including:
  - Evidence about whether or not computer-assisted learning increases a variety of specific student outcomes, in what ways and under what conditions;
    - At a level of detail to decide whether or not to invest in computer-assisted learning technology; and
    - At a level to choose among applications.
  - Practical information to make it easy for practitioners to find computer applications to meet particular needs (e.g., different ways of learning to read, different ways to teach calculus, approaches to rapid credit accumulation, etc.).
- Teacher training and development, including pre-service and in-service training. Training needs to cover, at least:
  - Ways in which technology supports cognition and high quality pedagogy so practitioners can infuse it throughout teaching and can develop their own applications;
  - Basic computer skills, including hardware and software use and maintenance;
  - Model applications for particular purposes; and
  - Supports to shift the role of teacher from a dispenser of information to a facilitator who manages the environment and materials.
- Access and saturation, that is, enough computers for all students to have access in each classroom and for in-class work, research and homework; and
- Adequate resources to implement the above.

IV. POSSIBLE STRATEGIES FOR INVESTMENTS

No one best strategy for investment emerges from the findings summarized in this report. Rather, what emerge are several possible places to intervene to move work forward. Further, because so many people are already working on the infusion of computer-assisted learning into schools and alternative programs, there are many possible funding partnerships among foundations, corporations, government, universities and teacher training programs and education providers (school districts, schools, alternative programs, etc.).

Thinking specifically about supports to at-risk students, we believe there are four important categories of work that individual funders, or more likely, consortiums of funders could pursue. They are:

- Work to enable the development of high quality computer applications (software, websites, project and competency-based computerized curricula) that build intentionally on state-of-the-art cognitive theory to achieve specific learning goals;
- Work to allow educational providers that serve significant numbers of at-risk students (school districts, schools, alternative programs, corps) to implement the minimum set of conditions necessary for computer-assisted learning to produce maximum benefits in places that serve at-risk students;
- Work to promote creation of policy and economic strategies that equalize access to computer-assisted learning under the minimum necessary set of conditions; and
- Work to expand the quality and availability of supports necessary for these things to happen, that is — appropriate forms of teacher preparation and training; information on specific uses of computer-assisted learning for specific purposes and research on benefits to students, necessary conditions for success, costs and cost-effectiveness.

As noted earlier in this briefing paper, there are many efforts going on now to address some of these issues. With those efforts in mind, and thinking more specifically about benefits to at-risk students, there are also some particular gaps in the field that a foundation and its funding partners could address. Some investment ideas that might be particularly useful for at-risk students include:

- Research and development to create applications, using state-of-the-art cognitive theory, that help students master critical ‘gatekeeping’ subjects (writing, computational skills, algebra, ninth grade English, etc.) that to a large extent determine their academic progress and opportunities in traditional settings;
- Research and development to align currently respected computer-assisted learning software and programs with individual diploma requirements, state standards and other external accountability measures;
- Research on effective strategies, and development of implementation or replication materials to document and expand programs that help students in non-traditional settings obtain their high-school diplomas through competency and project-based instruction independent of time-in-seat;
- Research on effective strategies, and development of implementation or replication materials that schools, school districts and alternative programs can use to promote multiple, simultaneous uses of computers that they already own, in order to produce a wider variety of benefits for more students;
- Research to determine the minimum necessary bundle of conditions that need to be in place for computer-assisted learning to produce consistently positive benefits, and development of implementation or replication materials to help schools, programs and school districts put in place sufficient strategies at minimal necessary cost;
- Dissemination of the information that would be generated from these investments widely through existing clearinghouses and resources that educational leaders (principals, teachers, associations of alternative and community-based programs, Jobs Corps directors, etc), policymakers (state legislators, governors,

Investing in Computer-Assisted Learning (cont)

state boards of education and their federal and local counterparts), parents and advocates use;

- Dissemination of information that the implementation of these ideas could generate through public and targeted media to reach employers and voters. The goal would be to stimulate debate and action about resource allocation and equity issues that underlie distribution of computers and use of computer-assisted learning; and
- At some later point, when optimal conditions for success are in place in more settings, a wave of research to revisit the consistency and extent of benefits produced by computer-assisted learning.

TABLE 1: EXPERTS INTERVIEWED	
Name	**Areas of Work**
Gene Bottoms Senior Vice President Southern Regional Education Board	Mr. Bottoms has a major focus on project-based learning. He is working to develop a training program for teachers using best practices in technology-assisted instruction. He has also worked to develop a database of reviews of educational software
Ephraim Weinstein Vice President of the Department Center for Youth Development Corporation for Business Work and Learning	Mr. Weinstein designed Diploma Plus, a program designed to help out-of-school students receive a high school diploma, begin their post-secondary education and gain work experience.
Mary Jane Clancy Executive Director Education for Employment Office School District of Philadelphia	Ms. Clancy oversees the Twilight School Initiative in Philadelphia Public Schools. Twilight Schools offer a fast paced learning environment that allows adult students (18–24 years of age) to receive a high school diploma.
Joanna Fox Director Urban Network Initiative	Ms. Fox specializes in providing technical assistance and support to eight urban districts and their high schools.
Daniel Grego Director of Educational Services Shalom High School/Trans Center for Youth, Inc.	Mr. Grego has over twenty years of experience in providing educational services to adjudicated and at-risk students through alternative schools. In these schools, students have more input in the school operation (e.g., implementing discipline procedures for their peers, they have more to say about the curriculum, how they earn credits).
Mark Isenberg Director of Education, Training and Youth Services/Information Technology Services Supervisor Action for Boston Community Development	Mr. Isenberg works with alternative schools that employ the Diploma Plus model.
Terry Johnson Director of the Center for Public Health Research and Evaluation Job Corps/Battelle Human Affairs Research Centers	Mr. Johnson designed the study of computer-assisted instruction in Job Corps. He tested off-the-shelf computer packages as part of the research design and analysis.

TABLE 1: EXPERTS INTERVIEWED (continued)	
Name	**Areas of Work**
Gary Kaplan Executive Director Jobs for Youth, Boston	Mr. Kaplan focuses on using computers in out-of-school contexts to provide GED preparation and testing for adult students.
Melissa Kelley Program Officer Walter S. Johnson Foundation	Ms. Kelley's area of focus is education for children involved in the Juvenile Justice system
Mike Klonsky Founder Small Schools Workshop University of Illinois at Chicago	Mr. Klonsky works with several hundred comprehensive schools around the country. The Small Schools Workshop has a set of principles in which technology plays a key role, both for communications and as part of the curriculum for students and teachers. They try to infuse these principles in the schools with which they work.
Harry Bruell Vice President for Field Services National Association of Service and Conservation Corps	NASCC has 120 organizational members — ranging from big corps like City Year and a few huge Americorps programs, and the CCC to small corps with 15 students in one group. Mr. Bruell has worked to create a staffing position to allow someone to be with the corps members at the work site and in the education component, to ensure education and work components are integrated with each other.
Phil Matero Education Director L. A. Conservation Corps	The L. A. Conservation Corps employ project-based learning strategies. Specifically, it gives adult students experiential, life-relevant, hands-on activities, and focuses on integrating academic studies with work projects.
Stephanie Smith Program Officer Academy for Educational Development	Ms. Smith's work focuses on schools that are run by community-based organizations and offer programs that are designed to meet each student's individual needs.

TABLE 1: EXPERTS INTERVIEWED (continued)	
Name	**Areas of Work**
Jean Thomases Independent Consultant Academy for Educational Development	Ms. Thomases works as the consultant on the Community-based organization (CBO) schools project. CBO schools integrate youth development and educational practices. They look holistically at the needs of young people and development of competencies.

TABLE 2: USES OF COMPUTERS TO SUPPORT STUDENT OUTCOMES		
USES	**BARRIERS/CHALLENGES**	**COMMENTS**
To achieve core curricular or learning goals — for basic pedagogy For example:Apple Classrooms of Tomorrow Myriad examples of project-based applications, particularly in math and the sciences	Insufficient research to identify applications that have demonstrated effects on student learning in specific subjects for specific learning goals Represents a marked change in how teachers do their work, for which most are untrained Examples often not aligned with state standards Minimum conditions for success not generally in place (e.g. not enough computers to use computer-assisted learning as the basic instructional tool Saturation, — e.g. not enough computers in a classroom to convert to computer-assisted learning as the basic method of instruction	There are several features of computers and computer-assisted learning that mirror the elements people promote as good pedagogy and good education reform (see body of briefing paper) Several experts believe that using computer assisted learning for basic pedagogy can't really hurt any student, and may be the one option that works for some
To expand the courses a school can offer (e.g. via distance learning or internet courses) For example: Often used to provide SAT preparation, foreign language and AP courses to students attending schools or programs that do not offer these courses. (Please note: we understand the Mott Foundation has commissioned a report on distance learning that will cover this topic, so we did not explore it except in a very cursory way for this briefing paper).	Experts believe that distance learning requires more maturity and self-discipline than some students possess Requires special hardware and technology skills	Students in very small schools, alternative settings and/or in schools with many poorly performing students are often excluded from advanced curriculum. Distance learning is being used to reduce or eliminate this problem.

TABLE 2: USES OF COMPUTERS TO SUPPORT STUDENT OUTCOMES (continued)		
USES	**BARRIERS/CHALLENGES**	**COMMENTS**
To help students obtain high school credentials (e.g. approaches to rapid credit accumulation not based on time in seat; GED preparation courses) For example: High School Redirection Diploma Plus Learning Education Alternative Program (LEAP) Job Corps Myriad GED preparation programs	Lack of information to choose among approaches Lack of easily accessible and practical replication materials Policy, cost and implementation issues related to the creation of alternative educational approaches	Given the higher value of a high school diploma in comparison to a GED, computer-assisted rapid-credit accumulation strategies may allow students who would traditionally opt for a GED to attain a high school diploma instead. Note: many people use the terms computer-assisted instruction or CAI to refer mostly to GED preparation software, and for that reason, disparage computer technology for learning
As an assistive device (e.g. to manage hearing, visual or other physical or processing challenges) See Technologies for Remediation and Compensation of Learning Disabilities for more information	Cost of specialized equipment for individual students, and at scale for every student who could benefit	The benefits of computers for these purposes are well understood and highly valued among students, educators and families
To teach and allow students to master increasingly essential computer or technology skills (e.g. word processing, data base management, graphic presentations and internet search functions) For example: Standards developed by CBO schools and service and conservation corps Technology competencies for the Philadelphia School District NETS standards	Inequitable access to computers, particularly for poor people and people living in poor neighborhoods Not yet a state standard except in a few model statesSaturation — e.g. not enough computers in a classroom for every student to have enough time on the equipment to master basic skills	Much of the push towards this usage comes from parents. Surveys of parents indicate they believe that children who do not master basic computer skills in early grades in school are at a disadvantage in school and in competition for post-secondary education and jobs

TABLE 2: USES OF COMPUTERS TO SUPPORT STUDENT OUTCOMES (continued)		
USES	**BARRIERS/CHALLENGES**	**COMMENTS**
To improve connectivity and free-up instructors time via computerized management, administration and communication tools For example: Student to Student Connections for Learning Myriad administrative and management examples outside school settings	Costs for equipment, wiring, maintenance, upgrading, etc. Lack of leadership or vision to think of using computers in multiple, simultaneous ways	Some experts believe that schools won't really embrace computer-assisted learning until they also use computers for productivity and connectivity. They believe adoption comes from a "critical mass" of uses that forces greater facility and produces tangible benefits.

APPENDIX A1: POSSIBLE OUTCOMES AND BENEFITS FROM COMPUTER-ASSISTED LEARNING		
OUTCOMES		
Possible long term outcomes	**Shorter-term individual benefits**	**Shorter-term institutional benefits**
Students have improved standardized test scores *Chang, H., Henriquez, A., Honey, M., Light, D., Moeller, B., & Ross, N. (1998). The Union City Story: Education Reform and Technology Students' Performance on Standardized Tests. Center for Children & Technology* *Mann, D., Shakes haft, C, Becker, J. & Kottkamp, R. (1999). West Virginia Story: Achievement gains from a statewide comprehensive instructional technology program. Santa Monica, CA: Milken Family Foundation*. *Valdez, G., McNabb, M., Foerstch, M., Anderson, M., Hawkes, M. & Raack, L. (?). Computer-based technology and learning: Evolving uses and expectations. Oakbrook, IL: North Central Regional Educational Laboratory*	Students Students learn faster Students retain more content Students spend more time on education-related tasks Students have improved school attendance *Cotton, K. (1992). Computer-assisted instruction. Portland, OR: Northwest Regional Educational Laboratory*. Students have improved spelling Students have improved reading comprehensionStudents have increased vocabulary *(Gay, G.) 1996. Technologies for remediation and compensation of learning disabilities. Ontario Institute for Studies in Education*, www.snow.utoronto.ca/Learn2/greg/*compnld.htm* Students have improved writing skills Students complete units of study more quickly Students have improved test scores Students have increased social*)*	Lower cost for intervention programs by "leveraging" teacher instruction *(*www.softwareforsuecess.org/*about.html)* School approaches to teaching and learning change form being curriculum-centered to learner-centered, from individual tasks to collaborative-tasks, from passive learning to active learning. *Dwyer, D. (1995). Changing the Conversation about teaching, learning & technology: A report on 10 years of ACOTresearch. Apple Computers*. More cost-effective than other reform strategies including reduced class sizes *Mann, D., Shakes haft, C, Becker, J. & Kottkamp, R. (1999). West Virginia Story: Achievement gains from a statewide comprehensive instructional technology program. Santa Monica, CA: Milken Family Foundation*. More cost-effective than tutoring

APPENDIX A1: POSSIBLE OUTCOMES AND BENEFITS FROM COMPUTER-ASSISTED LEARNING (continued)		
OUTCOMES		
Possible long term outcomes	**Shorter-term individual benefits**	**Shorter-term institutional benefits**
	awareness Students have increased confidence Students use technology routinely and more appropriately *(Dwyer, D. (1995). Changing the Conversation about teaching, learning & technology: A report on 10 years of ACOT research. Apple Computers.)* Students have improved performance in specific subject areas (e.g., mathematics, writing, reading) *(Chang, H., Henriquez, A., Honey, M., Light, D., Moeller, B., & Ross, N. (1998). The Union City Story: Education Reform and Technology Students' Performance on Standardized Tests. Center for Children & Technology)* Students have improved higher-order thinking skills *Educational Programs That Work — 1995: Computers Helping Instruction and Learning Development (Project CHILD),* www.ed.gov/pubs/EPTW/eptw10/ *eptw10a.html* Students will have an increased ability to work collaboratively www.ed.gov/pubs/EdReformStudies/ *EdTech/csile.html*	*Cotton, K. (1992). Computer-.assisted instruction. Portland, OR: Northwest Regional Educational Laboratory*

APPENDIX A1: POSSIBLE OUTCOMES AND BENEFITS FROM COMPUTER-ASSISTED LEARNING (continued)		
OUTCOMES		
Possible long term outcomes	**Shorter-term individual benefits**	**Shorter-term institutional**
	Students have fewer retentions Students have fewer discipline referrals Students have higher self-esteem Students have more positive attitudes about school *Educational Programs That Work — 1995: Computers Helping Instruction and Learning Development (Project CHILD),* www.ed.gov/pubs/EPTW/eptw10/ *eptw10d.html* Teachers Teachers more effectively teach economically disadvantaged children to read (www.softwareforsuccess.org/about.html	

APPENDIX A2: RECENT INNOVATIONS IN TECHNOLOGY		
Reference	**Innovation**	**Change**
Everett, T. Computer assisted instruction and the learning disabled: Factors that must be addressed for a successful program, 141.218.70.183/SPED603/paper Everett.html	Software with user control options that make them more suitable for learning disabled students Software that include problem solving, feedback, speech enhancement, ability to lend itself to group interaction, user and teacher control options, adaptability, and the ability to meet the students instructional needs among other features **Dedicated space (classrooms or laboratories) with additional resources and personnel**	Shift in role of teacher from a dispenser of information to a facilitator who manages the environment and materials Teachers trained and feel comfortable with the computer as a teaching tool Teachers actively use computers and CAI tools for investigation, augmenting instruction, and collecting performance dataIncreased opportunities to use computers Coordination of computer-related activities with individualized education program (IEP)
Keup, J. R. Using technology in remedial education. ERIC Clearinghouse for Community Colleges, www.gseis.ucla.edu/ERIC/digest s/dig9810.html	Computer aided instruction in remedial education Interactive teacher-student journal [INVEST (Nova Scotia Community College)] Instructional management system for basic skills development [Project SYNERGY (Miami-Dade Community College)]	Students are expected to write comments, concerns and questions on a daily basis, and the instructor reads and responds to the student communication Instructors set preferences, monitor the students' progress, receive reports, modify the curriculum, send e-mail, and personally intervene in the learning process.
Educational Programs That Work, Chapter I Higher Order Thinking Skills Project (H.O.T.S.) www.ed.gov/pubs/EPTW/eptw10/ 1ptw10a.html	A lab is equipped with Apple computers (Apple IIe, Apple IIgs, or Macintosh LC) and H.O.T.S. software	Use a detailed and creative curriculum to combine use of computers with drama and Socratic dialogue. Teachers are trained in Socratic dialogue techniques.

APPENDIX A2: RECENT INNOVATIONS IN TECHNOLOGY (continued)		
Reference	**Innovation**	**Change**
Buddy Project	Place a computer in the home of every Hoosier child grades 4 through 12 to extend learning beyond the classroom. Supply students with home computers and modem access to school	The teachers integrate technology into the curriculum in every class. The Buddy model includes - Focus on 4th & 5th grade students & families - Classroom clusters in school - Extensive staff development - Family training and support
Dwyer, D. (1995). *Changing the conversation about teaching, learning & technology: A report on 10 years of ACOT Research*. Apple Computers	Each student and teacher is given two computers — one for home and one for school	Characteristics of successful staff development: - Constructivist learning environment - Situated staff development (working in real classrooms with real students) - Time for reflection through group discussion and writing in a journal help teachers to question their own beliefs and to begin the process of change - Specific plans for change (i.e., transfer of new ideas into their own classrooms) - Immediate and ongoing follow-up support

APPENDIX A2: RECENT INNOVATIONS IN TECHNOLOGY (continued)		
Reference	**Innovation**	**Change**
Wenglinsky, H. (1999). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Princeton, NJ: Educational Testing Service.	Use computers to teach higher order thinking skills Use computers for learning games Increase numbers of computers in homes	Increased tendency of teachers to use computers for learning games as a result of professional development Increased use of computers in homes
Becker, H. J. (January, 2000). Findings from the teaching, learning, and computing survey. A paper written for the School Technology Leadership Conference of the Council of Chief State School Officers, Washington, DC.	Increase classroom access to clusters of computers	Increase teacher expertise and comfort in using computers professionally Shift teacher philosophy from Transmission oriented to Constructivism[5] Schedule longer blocks of time for individual classes
Simic, M. R. Guidelines for computer-assisted reading instruction, www.kidsource.com/kidsource/content2/guidelines.computers.html	Research studies indicate clearly that computer instruction is effective for a wide variety of reading skill and concept areas.	The emphasis should not be on using computers to increase reading and writing achievement, but rather on whether teachers use computers for meaningful reading and writing instruction, or are locked into computer-based drill and practice software.
Educational Programs That Work — 1995, Computers Helping Instruction and Learning Development (Project CHILD), www.ed.gov/pubs/EPTW/eptw10/eptw10d.html	A Project CHILD classroom is organized with learning stations, and each has a computer station with 3–6 computers, a teacher station for small-group instruction, textbook and writing stations, and hands-on activity stations.	Computers Helping Instruction and Learning Development (Project CHILD) seeks to modify the school structure and create classroom conditions conducive for learning with technology, create cohesive units of work that foster strategies for thinking, and realign curriculum for reading, language arts, and mathematics. It provides a system for fully integrating technology into reading, math, and language arts, and classroom management techniques for using computers

APPENDIX A2: RECENT INNOVATIONS IN TECHNOLOGY (continued)		
Reference	**Innovation**	**Change**
1999 Research Report on the Effectiveness of Technology in Schools: Executive Summary, 6th Edition. Software Publishers Association.	To positively impact student achievement and student motivation/self-concept specific software design elements are highly desirable: 1. Offering students some control over the amount, review and sequence of instruction can result in higher achievement and better student attitudes toward learning than having the software control all instructional decisions. However, low-achieving students and students with little prior content knowledge are likely to require more structure and instructional guidance than other students are. 2. In tutorial and practice software, programs with feedback providing knowledge of correct responses were found to be superior to programs that require students to answer until they are correct. Furthermore, feedback that identifies why a response is wrong was found to be more effective than feedback that only identifies what was wrong. • 3. Software that includes embedded cognitive strategies provides students with a learning advantage. Helpful cognitive strategies include repetition and rehearsal of content, paraphrasing, outlining, cognitive mapping or diagramming, drawing analogies and inferences,	Specific characteristics of the learning environment help to maximize the benefits of educational technology: 1. District-level involvement and the leadership of a school-level computer coordinator are key factors in developing a school environment conducive to effective use of technology. 2. Educators are more effective after receiving extensive training in the integration of technology with the curriculum. 3. Exemplary computer-using educators benefit from a social network of other computer-using educators at their school. 4. Exemplary computer-using educators typically have smaller class sizes and more funds available for software acquisition. 5. Educators should carefully plan, and actively participate in, learning activities that incorporate tool software. Before students use database software independently, they should be given search strategy training. 6. Educators should offer students self-directed learning experiences and activities that encourage self-expression. 7. Students benefit from personal interaction among class members.

APPENDIX A2: RECENT INNOVATIONS IN TECHNOLOGY (continued)		
Reference	**Innovation**	**Change**
	generating illustrative examples, specific techniques for reading in the content areas and using pictorial information. 4. Students can benefit academically from software with embedded conceptual change strategies — sequences of instruction that move students from their faulty preconceptions to a more accurate understanding of the concepts involved. 5. Animation and video can enhance learning when the skills or concepts to be learned involve motion or action. 6. Content-related graphics (both static and animated) and video can help improve student attitudes and motivation in mathematics and science. 7. Students using hypermedia software can benefit from an interface that includes a graphical browser or navigation map that shows the links among the various screens of information. 8. Foreign language and ESL students can benefit from presentation of video segments with captioning (i.e., subtitles in the target language). 9. Recent research suggests further exploration possible inclusion of the following software design characteristics:	

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APPENDIX A2: RECENT INNOVATIONS IN TECHNOLOGY (continued)		
Reference	**Innovation**	**Change**
	• Stating objectives • Multitiered scaffolding of instructional support • Requiring note taking • Story and fantasy contexts • Game contexts with content-related visual metaphors • Multiple window presentation options (overlapping vs. tiled windows) • Dynamic visualization of abstract concepts • Still graphics in vocabulary development Advanced organizers in simulations	
1999 Research Report on the Effectiveness of Technology in Schools: Executive Summary, 6th Edition. Software Publishers Association.	Educational technology has significant positive effects on both achievement and student attitudes for special needs populations. Speech recognition is an especially valuable compensatory tool for the learning disabled.	

APPENDIX A2: RECENT INNOVATIONS IN TECHNOLOGY (continued)		
Reference	**Innovation**	**Change**
Mann, D., Shakeshaft, C, Becker, J., & Kottkamp, R. (2000). West Virginia Story: Achievement gains from a statewide comprehensive instructional technology program.	Beginning with the kindergarten class of 1990–91, hardware and software — focusing on the State's basic skills goals in reading, language arts and mathematics — were installed in schools.	Professional development for teachers in the use of the software and the use of computers in general. Additional explanations for test score gains: • The state spent $430 million to renovate 470 school buildings • In 1990, a statewide strike led to substantial pay increases for teachers • The State Legislature also required local school councils, faculty senates, school site accreditation visits and a "probation" procedure • Each school was required to have a "Unified School Improvement Plan

APPENDIX A3: FINDINGS OF FOUR META-ANALYSES				
Study	I Ryan, A. W. (1991). Meta-analysis of achievement effects of microcomputer applications in elementary schools. *Educational Administration Quarterly, 27*(2), 161–184.	Kulik, C. C. & Kulik, J. A. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior, 7,*75–94.	Fletcher-Flinn, C. M. & Gravatt, B. (1995). The efficacy of computer — assisted instruction (CAI): A meta-analysis. *Journal of Educational Computing Research, 12*(3), 219–241.	Xin, Y. P. & Jitendra, A. K. (1999). The effects of instruction in solving mathematical word problems for students with learning problems: A meta- analysis. *The Journal of Special Education, 32*(4), 207–225.
CAI versus other strategies	The mean of the 58 effect sizes in this meta-analysis was .309, the median .296, and the range–.482 to 1.226. An effect size mean of .309 indicates that the average student in the treatment groups exceeded the performance of 62% of the students in the control groups. In terms of grade equivalent units, .309 can be interpreted as one-third greater then the expected gain in a school year, or in terms of grade-equivalent units, approximately three months additional gain.	The average ES in the 248 studies was 0.30; its standard error was 0.029. This average ES means that in the typical study, the performance of CBI students was 0.30 standard deviations higher than the performance of the control students. We conclude therefore, that the typical student in an average CBI class would perform at the 62nd percentile on an achievement examination, whereas the typical student in a conventionally taught class would perform at the 50th percentile on the same examination. Put another way, the average student from the CBI class would outperform 62% of the students from the conventional classes.	The average effect size was calculated as .24. This means that in the average study, students in the CAI classes had scores that were .24 standard deviations higher than those of comparison students with more traditional forms of instruction. In terms of percentiles, CAI students would outperform 60 percent of the students from conventional classes.	CAI yielded the highest effect size followed by representation, strategy and other.

APPENDIX A3: FINDINGS OF FOUR META-ANALYSES (continued)				
Teacher training/professional development	The mean effect size for more than 5 hours of teacher training was significantly greater than 5 hours or less of teacher training			
Subject matter/concept being taught			No significant difference based on course content	The effectiveness of interventions involving one- step word problems was greater than that for multi- step and mixed word problems. The effect size of mixed word problems was greater than that of multi-step problems.
Educational strategy				The effect size for individually provided instruction was greater than that for small-group instruction.
Maintenance		Twenty studies examined the performance on follow-up examinations of CB1 and conventionally taught classes. Whereas the average ES on course examinations was 0.30 for all 242 studies, the average ES on final examinations for these 20 studies was 0.21. The average ES in the 20 studies was 0.17.		In terms of intervention approaches, CAI was seen to be more effective in promoting maintenance than generalization.
Generalization				Long-term interventions (more than 1 month) were most effective in promoting both maintenance and generalization.

APPENDIX A3: FINDINGS OF FOUR META-ANALYSES (continued)				
Attitudes about computers	Nineteen studies examined students' attitudes toward computers. The average effect size was 0.34.			
Attitudes about school		Twenty-two studies examined student ratings of the quality of instruction. The average ES in the 22 studies was 0.28.		
Attitudes about subject matter		Thirty-four studies examined the effects of CBI on student attitudes toward the subject matter that they were being taught. The average ES for student attitudes toward subject was 0.05, a very small positive effect.		
Student characteristics			No significant difference based on educational level	The effect size for students with LD was less than that for students with mixed disabilities and those at risk.No significant difference by grade/age between elementary and secondary studentsThe effect size for participants with IQ<85 was significantly greater than that for those with IQ greater than or equal 85.

APPENDIX A3: FINDINGS OF FOUR META-ANALYSES (continued)				
Duration of study			No significant difference based on duration of study	The effect sizes for short- term (Less than or equal to 7 sessions) interventions were seen to be more effective than intermediate (Greater than 7 sessions, less than or equal to 1 month), but less effective than long-term (greater than one month) interventions. These differences were significant.
Student direction				No significant difference between student-directed interventions and interventions with low student regulation.
Coordination of and communication with project teachers	No significant differences based on coordination of and communication with project teachers			

NOTES

1. Though we use the term “at-risk” in this paper, we are aware that many in the field object to the term, in large part because it is not very specific — it doesn’t really describe what is going on with a student — and because it has often been used to label students as failures.

2 Computers are used to support special education students in at least two different ways: as assistive or adaptive devices (e.g., to overcome specific kinds of physical barriers, like ability to turn pages or hear lessons) and as instructional tools that might be especially interactive, engaging or tailored to different learning styles. Findings from this second use are most relevant for improving educational outcomes of at-risk students as they are defined in this paper.

3 For example, literature from the school reform, small schools and effective schools movements often call for more individualized curriculum and/or a higher ratio of teachers to students; more student-centered learning; more teacher and student time on task; greater access to advanced content, particularly for low-performing students, that promotes higher-order skills; more cross-disciplinary and untracked classes and more relevant or real-world examples or learning opportunities. A review of Sack suggests common features of good programs or schools include: “competency-based models in which the program tells the learner prior to instruction what skills or knowledge he/she will be asked to demonstrate after instruction; competencies, though stated as minimums, encourage instructional opportunities and activities that enable students to achieve maximum levels of performance; and curriculum, instruction and assessment are explicit, known, agreed upon, integrated, adaptive and data-based” ([38] Sack, 3). Roschelle et.al., talk about the “four fundamentals of learning — active engagement, participation in groups, frequent interaction and feedback, and connections to real world concepts” ([36] Roschelle et.al., 76).

4 As described in “Children and Computer Technology: Analysis and Recommendations,” the National Research Council’s Computer Science and Telecommunications Board developed a conceptual framework to help in the development of competencies and standards. The Information Society for Technology in Education hosted a collaboration of stakeholders of stakeholders (schools, corporations, foundations, government, called NETS) that set standards for each grade level in: basic operations and concepts, social, ethical and human issues, technology productivity tools, technology communication tools, technology research tools and technology problem-solving and decision-making tools (41).

5 Developing student responsibility for selecting and carrying out learning tasks, emphasizing group work involving discourse, and the use of projects, products, and performances for outside audiences.

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