Occasional Paper No. 40

Factors Influencing Technology's Effect on Student Achievement and a Caution About Reading the Research

by Abigail Garthwait
College of Education & Human Development

December 2001

PENQUIS SUPERINTENDENTS' ASSOCIATION RESEARCH COOPERATIVE

The Penquis Superintendents' Association Research Cooperative is a collaborative endeavor between the Association and the University of Maine's College of Education & Human Development. Through the Center for Research and Evaluation, the Cooperative prepares papers of timely educational issues that impact education in individual districts, the Penquis region and/or the state. The goal of the cooperative is to link researchers and practitioners to meet the needs of Maine students.

PENQUIS SUPERINTENDENTS' ASSOCIATION RESEARCH COOPERATIVE
2001-2002

John Backus
MSAD #23 & #38

William Braun
MSAD #48

Lester Butler
MSAD #46

Brent Colbry
Millinocket School Department

Keith Cook
MSAD #31

Patricia Duran
Hermon School Department

Robert   Ervin
Bangor School Department

Jeffrey Fish
MSAD #30, Union #110

William Folsom
Union #60

Raymond Hart
MSAD #63, CSD #8, Dedham

Richard Lyons
MSAD #22

Sandra MacArthur
Union #113

Owen Maurais
Old Town School Department

Leonard Ney
MSAD #64

Richard Norton
Dedham School Department

Keith Ober
Union #90

Matthew Oliver
MSAD #4

Charles Pease
MSAD #25

Thomas Perry
Union #87

Gilbert   Reynolds
Harmony School Department

Donald Siviski
MSAD #68

Douglas K. Smith
Glenburn School Department

Allan Snell
Union #91

David Walker
MSAD #41

Betsy Webb
Brewer School Department

Fred Woodman, Jr.
MSAD #67

Factors Influencing Technology's Effect on Student Achievement and a Caution About Reading the Research

Abigail Garthwait

College of Education & Human Development
University of Maine
5766 Shibles Hall
Orono, ME 04469-5766

December 2001

1865 THE UNIVERSITY OF
MAINE

A Member of the University of Maine System

Abstract

Many factors may contribute to the influence of computers on learning: access to home computers, first language, gender, and academic history, among others. However, only some factors can be directly influenced by schools. This paper identifies three key school related factors that influence technology's effect on student achievement: instructional goals; the match between goals, instructional strategies, and assessment tools; and staff development.

Introduction

     Three decades of research relating to the effects of computer technology in education have ranged from experimental studies (control and treatment groups) to quasi-experimental (pre and posttests) to meta-analyses. Researchers have posed questions about a myriad of topics: time on task, anxiety, motivation, change in test scores, collaboration, gender/socioeconomic discrepancies, and health and safety habits. Other studies have employed qualitative measures to examine whether technology can foster collaboration or serve as a constructivist tool. Educational decision makers may be intimidated by the interrelated and confounding factors of software, hardware, people, and context, but are still accountable for reconciling the time and expense related to technology with the educational benefits. Many factors may contribute to the influence of computers on learning: access to home computers, first language, gender, and academic history, among others (Edwards, 2001). However, only some factors can be directly influenced by schools. This paper identifies three key school related factors that influence technology's effect on student achievement: instructional goals; the match between goals, instructional strategies, and assessment tools; and staff development. In addition, it will also present a few of the complex issues involving the literature of the field: the crucial importance of thoroughly reporting definitions and research results and the difficulties in aggregating studies with differing ideological stances.

     In this paper *technology* and *instructional technology* will refer interchangeably to computers, not items such as slide rules, overhead projectors or graphing calculators, although these do fit within a broader definition of *technology*. *Assessment of student achievement* is another term in need of clarification. Some researchers (e.g., Mann, Shakeshaft, Becker, & Kottkamp [1999]; Wenglinsky [1998]) define student achievement as a score on a standardized test (NAEP and Stanford 9, respectively), while others call for a broader view of assessment that includes both quantitative and qualitative measures of learning. Seymour Papert (1993) illustrates the need for multifaceted, comprehensive assessments with the example of a factory director who gets a bonus for achieving the company's goal of making 150 tons of super-sized nails, though

they happen to be nails that are too big for anyone to find useful! He concludes, "Defining educational success by test scores is not very different from counting nails made, rather than nails used" (p. 208). Congruent with Papert's view of assessment, Grant Wiggins and Jay McTighe (1998) explicate a system in which performance assessment is matched with instructional goals in *Understanding by Design.* Tierney, Carter, and Desia (1991) were early proponents for portfolio assessment and their themes have been extended into the growing field of electronic and digital portfolios. The intricacies inherent in just defining these two terms (*technology* and *assessment of student achievement*) reveal some of the difficulties facing administrators who must justify budget decisions based on educational value.

Small-scale Research

Studies using a small number of students may pave the way for better understanding of educationally effective uses for computers. For example, Turner and Dipinto (1992) noted a major unanticipated finding in a research project of 37 seventh-grade students: "With traditional written reports, students usually make revisions only after the teacher has corrected their drafts. Using [tool software], however, the students made an enormous number of spontaneous text revisions" (p. 196). Similar results were found by Finkelman and McMunn (1995) as they studied 19 sixth graders creating an electronic author study. The students tended to revise their writings more often in the multimedia program. Furthermore,

> All of the students reported that they learned more about their author and learned how to better organize their thoughts through use of [the program]. All of the students followed the traditional steps in the writing process: planning, prewriting, drafting, editing, revising and publishing. Students reported that this project provided a stimulating learning atmosphere, making the process more enjoyable. (p. 24)

If an educational goal is to foster reflection and redrafting of written work (Atwell, 1998; Calkins, 1994), then it follows that the computer, a tool which facilitates motivation and ease of revision, matches the instructional goals .

Exciting research results have been produced by participant observers on a small classroom scale. Yasmin Kafai (1995) describes a project in a low socioeconomic school in which 16 fourth graders used the computer language Logo to develop fraction games for younger students. In *Minds in Play: Computer Game Design as a Context for Children's Learning,* Kafai explores the epistemology of the students working in a constructionist design environment. She notes, "the students improved significantly in their understanding of fractions and flexibility in moving between different representational modes" (p. 302). Kafai highlights two instructionally insightful conclusions: "long-term involvement in the project was essential for students' learning" (p. 290) and by the "creation of a rich and complex learning environment. . . . the nature of this learning culture represented the complexities of the everyday world in which children learn" (p. 293). As educational decision makers are formulating policy and educators are mapping out instructional strategies and assessment tools, it is important that they acknowledge the need for adequate time and a carefully structured classroom climate.

The American Institutes for Research reported their investigation of several promising projects (Coley, 1997). Twenty-two fourth- and sixth-grade classes (from seven urban districts) investigated civil rights. The researchers found that fourth graders having and using on-line access placed significantly higher on two of nine learning measures; sixth graders measured significantly higher on four. A 4-year study by the Office of Educational Research and Improvement (U.S. Department of Education as cited in Coley, 1997) that looked at technology in constructivist classrooms, found that five of the eight schools had higher test scores than a comparison group. In this case, a wide range of carefully targeted resources were easily available only by using computers. The unit and the accompanying instructional strategies matched the information literacy goals of the lesson.

While it is beyond the scope of this paper to explore the connection between motivation and achievement, it should be noted that a significant amount of research at the classroom level has found positive results in the affective realm. Beichner (1994) documented seventh graders who were so enthusiastic about their work creating multimedia zoo kiosks that they often came

to school early, left late, and skipped lunch and study halls. Related affective observations were noted by Riddle (1995) in his study of 18 fourth-grade students. He noted one boy with chronic discipline problems in the regular classroom. This student remained consistently on task and was reluctant to leave the computer when the period was over. Riddle underscores the motivational component, "all students said that they were proud of their work and the majority credited this pride to the fact that they worked hard" (p. 22). While working towards instructional goals, educators want to use tools which have been documented as motivational.

Repman, Weller, and Lan (1993) investigated the variations in social context for 98 eighth graders working with a hypermedia based unit on computer ethics. Their study serves to illuminate the interrelationships between technology and pedagogy. They noted a trade off between the accomplishments of the gifted and talented students' and the nongifted and talented students. "When magnet students worked in heterogeneous pairs, mean scores were approximately one standard deviation lower than the scores for magnet individuals or homogeneous pairs. At the same time, pairing of any kind improved the achievement of non-magnet students" (p. 294). While the researchers cautioned against making elaborate conclusions based on this study, they did see benefits in grouping the nongifted and talented students for the hypermedia lesson.

Classroom-size studies can assist in pointing out the complexities of integrating technology and instruction. As part of their qualitative study, Lundeberg, Coballes-Vega, Standiford, Langer, & Dibble (1997) posed the question, "Are students constructing knowledge as they construct projects?" as they investigated a geography unit taught by two elementary school teachers. The end project was a collaborative hypermedia stack which the small groups presented to the class of 40 students. The researchers noted the intense engagement and motivation of the students but concluded that the technology functioned as a mask for the lack of quality in some of the projects. The teachers seemed to view a polished end product as evidence of student learning, even though it was clear during the construction stage that more technologically proficient students dominated the keyboards. "A number of these projects probably would have been

more critically assessed if they had been in traditional form. In some cases, information was copied verbatim, missing or simply erroneous" (p. 79). The conclusion is not that technology sidetracks student learning but that teachers must restructure their classrooms and assessment systems to accommodate fundamentally different ways of learning. From Kafai's carefully crafted design environment to utilization of editing software in both Turner and Dipinto (1992) and Finkelman & McMunn (1995), the teacher is a pivotal force in making the best use of instructional technology. Pedagogy is key.

Meta-analyses and Long-term Studies

Yuen-Kuang Liao (1998) conducted a meta-analysis of 35 studies in order to synthesize the research comparing the effects of hypermedia on students' achievement. The researcher suggests the effects were moderately positive when compared to traditional instruction (effect size 0.48). The result that educators might find useful is the statistically significant impact of the type of hypermedia delivery. The studies in which simulators (software "using vivid situations for learning") were employed showed significantly higher results than studies in which computer-based interactive videodisc or multimedia were used. Therefore, hypermedia programs which more actively involved the students resulted in higher achievement than those which put the student in a more passive role (Ayersman, 1996).

One of the difficulties in pinpointing technology's influencing factors is the speed at which computers are evolving. One can see the problematic nature of clustering studies which take place over extended time, if one pictures comparing a child laboriously entering DOS commands and his younger sibling effortlessly making movies on a laptop. Nevertheless, one meta-analysis that is still being used to promote technology is James Kulik's (1994) work which synthesized over 500 studies on computer-based instruction (CAI). He found that students in the treatment groups (those using CAI) averaged scores at the 64th percentile on achievement tests while control group students (i.e., same material without computers) averaged at the 50th percentile. Kulik also noted that the CAI instruction was more time efficient and produced students

with more positive attitudes towards learning. Most of the research examined by Kulik was done in the 1980s, when computer hardware and software was vastly different from that available today. Kulik's (1985, 1990, 1994) recurring updates showing positive student achievement related to computer use may indicate that the significant results are not merely a result of the "novelty effect" (i.e. that the newness or novelty of the experimental approach doesn't have undue effect on the conclusions).

Attempts to consolidate complex data from more than one discipline, grade level, or even software application potentially muddies the results of meta-analyses. The wide array of products that contain computer chips (pdas, digital cameras, networks, cell phones, etc.) further complicates definitional delineations. Differences in students' developmental skills add an additional dimension: "Implementations of these innovations takes place from kindergarten through high school, and the attributes of successful integration may not be the same across these levels" (Painter, 2001, p. 22).

It would be remiss not to add a word about the possibility of biased results in research and reports commissioned or sponsored by computer or software firms. A meta-analysis by Jay Sivin-Kachala and Ellen R. Bialo (1994) and their subsequent updates (including one in 1999) are highly visible (Coley, 1997; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Schacter, 1999). The original study found measurable positive differences in student achievement and attitudes towards learning due to the effect of technology. An alert reader would notice that the update carries the information that the authors are identified as President (Bialo) and Vice President (Sivin-Kachala) of Interactive Educational Systems Design. Both the study and its update were published by The Software Publishers Association.

A contrasting study, also sponsored by a computer firm, does not set out to prove that using computers in K-12 education brings a rise in student achievement results. Instead, these researchers wished to set up computer-rich environments and document what happened. Research sponsored by Apple Computer, (Apple Classrooms Of Tomorrow, ACOT) investigated 10 years of intensive technology use. The collaborative included public schools, universities, and

research agencies. The results showed no significant difference in standardized test scores with comparison groups in the same school (students did not have both a computer at home and at school) (Baker, Gearhart, & Herman, 1994). However, the study documented other effects of computer use not measurable by a pencil and paper test. Students "explored and represented information dynamically and in many forms, . . . communicated effectively about complex processes, used technology routinely and appropriately, became independent learners and self-starters, knew their areas of expertise and shared that expertise spontaneously" among other changes (Coley, 1997, ¶ 21). Even self-proclaimed, techno-skeptic Larry Cuban was impressed. He wrote the introduction to *Teaching with Technology: Creating Student Centered Classrooms* by Sandholtz, Ringstaff, and Dwyer (1997).

> From five classrooms located in five different schools in which children, families, and teachers received computers and accessories, ACOT researchers learned soon enough that a saturation strategy failed to alter how teachers taught. . . . The researchers watched what happened, listened to teachers, and documented small, incremental, but significant changes in classroom practices. They recorded how classrooms became places of traditional and nontraditional teaching, imaginative hybrids of practice that emerged over time. (p. xiii)

One significant implication of this study is that the educators used the technology-rich environment to support substantial changes in their pedagogy, and the results were revealed in observable, documented student behaviors. However, the changes in student work took time and did not show up in standardized test scores.

Despite the zeal with which proponents of technology advocate computers in schools, there are cautionary voices. A number of important books (Healy, 1998; Postman, 1992; Roszak, 1996; Stoll, 1999) and articles (Alliance for Childhood, 2000; Henry, 1999; Kirkpatrick & Cuban, 1998) question the mindless proliferation of computers. The authors urge a more serious examination of this trend, especially with young children. In her book *Failure to Connect* (1998) Jane Healy writes:

> Educators are worried that education is becoming an adjunct to the technology business, a sort of training school for the high-tech world. We parents want to see

our children succeed, but the foundations for true success—even future technology "guru" status—rest on skills that will not become obsolete with the changing of a microprocessor. Most successful technology innovators did not grow up with computers, but rather with rich, internal imaginations. Many were divergent thinkers who failed to flourish in the traditional world of school. (p. 31)

Opponents express concern about excessive computer use to the detriment of creative and outdoor play, and to the potential of physical harms such as eyestrain, carpal tunnel syndrome, and poor posture. The underlying tenet posed by Healy and others hinges on the closeness of the match between the expressed goals for computers and the actuated student use, as well as the importance of oversight by all educators.

Nevertheless, most schools have progressed beyond the basic question, "Do computers belong in the classroom?" because parents, business and the community view their presence as a given. "Computers and the Net are simply preconditions for moving to a new paradigm in learning. . . . More importantly, [initiatives which put computers in schools] provide the children themselves with the tools they need to learn and to catalyze the rethinking of education" (Tapscott, 1998, p. 136). The pertinent question is not "Do computers make a difference?" but "What factors in technology use influence student achievement?"

In a provocative article entitled "Computers make kids smarter – Right?" Heather Kirkpatrick and Larry Cuban (1998) categorize single studies, meta-analyses, reviews, and other research into neat lines of pro and con. The concluding remarks could not be clearer. "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" (¶ 61).

A Closer Look at Two Large-scale Studies

The Milken Family Foundation produced a report in 1998 that has had considerable media coverage, "The Impact of Education Technology on Student Achievement" (Schacter, 1998). Harold Wenglinsky's (1998) work is one of the six featured studies. "Does It Compute? The Relationship Between Educational Technology and Student Achievement in Mathematics"

examines data from the 1996 National Assessment of Educational Progress (NAEP). The sample consisted of students in classrooms randomly selected by NAEP, comprising 6,227 fourth graders and 7,146 eighth graders. The results were controlled for teacher characteristics, class size, and socioeconomic status.

The three positive findings that Schacter reported from Wenglinksy are:

• Eighth-grade students who used simulation and higher-order thinking software showed gains in math scores of up to 15 weeks above grade level as measured by NAEP.

• Eighth-grade students whose teachers received professional development on computers showed gains in math scores of up to 13 weeks above grade level.

• Higher-order uses of computers and professional development were positively related to students' academic achievement in mathematics for both fourth- and eighth-grade students. (p. 7)

Schacter also lists two "negative findings" from Wenglinsky's report:

• Fourth-grade students who used technology to play learning games and develop higher-order thinking performed only 3 to 5 weeks ahead of students who did not use technology.

• Both fourth- and eighth-grade students who used drill and practice technologies performed worse on NAEP than students who did not use drill and practice technology. (p. 8)

Note the use of "only" in the first negative finding; it seems to indicate a positive effect, which was not as great as it might have been.

It is useful to introduce another research project, often cited with the Wenglinsky study (e.g., in Schacter, 1999), as a foil for examining the implications of his work; Mann et al.'s (1999) evaluation of West Virginia's Basic Skills/Computer Education (BS/CE). What makes West Virginia's initiative an intriguing project are its scope and focus. Two results were clearly evident: The comprehensive, statewide technology program had been fully implemented by the 8th year, and achievement scores had improved. Mann et al.'s purpose was not to offer approba-

tion or opprobrium, but rather to determine the extent to which West Virginia's gains in test scores could be related to BS/CE.

West Virginia's primary goal was to improve basic skills of its elementary students. In the school year 1990-1991 every kindergarten class in West Virginia received hardware, software, and teacher training. The hardware component consisted of three or four computers for each classroom, a printer, and a school-wide server. This comprehensive intervention followed in waves as these students moved up through the elementary school. While individual schools had some level of decision-making authority, it was held within strict parameters. Schools could decide whether computers would go in a centralized lab or be placed in the classroom, or a combination of the two. Schools were also allowed to choose either of the two recommended software packages.

The researchers selected 18 schools as the initial stratifier. Fifth graders ($n = 950$) were chosen because they were the only level to have 3 consecutive years of test scores and who also had the most continuous exposure to the technology initiative. Factor analysis was used to determine the effects of input phenomena, which were then related to variation in standardized test scores.

Given the significance of its conclusions, it is no wonder that the Mann et al. (1999) study has been widely quoted. "The BS/CE technology regression model accounts for 11% of the total variance in the basic skills achievement gain scores of the 5th-grade students" (p. 12), and the authors convincingly argue that 11% actually underestimates the real effect. The researchers looked at other areas also:

> While there are no differences in the amount of use between girls and boys, the girls were more likely to see computers as a tool and the boys as a toy. . . . In terms of gain scores, there were differences in only two areas related to gender— girls gained more in social studies and boys gained more in spelling. In math and reading, there were no gender differences. (p. 35)

Furthermore, "Those *without computers at home* gained more [than students with computers at home] in: total basic skills, total language, language expression, total reading comprehension and

vocabulary" (p. 34). In a separate report, attached to the original study, the principals analyzed the cost efficiency in relation to other interventions. They found that the initiative was more cost effective in improving student achievement than (a) class size reduction from 35 to 20 students, (b) increasing instructional time, and (c) cross-age tutoring.

It is critical to note that the West Virginia BE/CE Initiative is based on improving the *basic skills* (spelling, vocabulary, reading, and math) of its students. While vendors supplied a few packages that could be considered "tool" programs (e.g., *Children's Writing and Publishing Center),* most of the software falls within the category of drill and practice. Representative titles include: *Bouncy Bee Learns Letters and Words, Combining Sentences Series, Parts of Speech Series,* and *Skillsbank 96 Reading & Mathematics.* Therefore, the positive results (i.e., a rise in test scores) in West Virginia are attributed to the use of drill and practice software.

An apparent contradiction surfaces when comparing Wenglinsky's (1998) and Mann et al.'s (1999) student activities on the computers. Wenglinsky stated that the use of computers to teach lower-order thinking skills (defined as "drill and practice," p. 15) was *negatively* related to academic achievement (pp. 5-8). Mann et al. sees positive results with the same type of software. A closer look at the two original studies uncovers elements that clarify the situation. In Wenglinsky's full report, an umbrella statement prepares the reader: the study "found that the greatest inequities did not lie in how often computers were used, but in how they were used " (p. 5). He offers as definitional, "for eighth-graders as 'simulations and applications' for higher-order skills and 'drill and practice' for lower-order skills; for fourth-graders, higher-order thinking is measured from playing mathematical learning games" (p. 28). Thus "playing learning games" counted as spending time in higher-order thinking skills for fourth graders. Other researchers have noted that many popular "learning games," sometimes categorized as "edutainment," fail miserably in teaching math skills. For example, students may arrive at a correct answer (often a requirement for going to the next level) simply by random clicking. Some games allocate more screen time to rewarding behavior than in having the student practice mathematical computations (Smith, 1986). "Rewards" typically come in the form of dancing

rabbits or multiple chances at shooting down alien space ships. A salient precondition for software use in the classroom is embedded in a section on Mann et al.'s report entitled "Policy Inputs." "Both vendors provided correlation matrices to the texts on the West Virginia adoption lists and to the standardized assessment tool selected by the state" (p. 17). It demonstrates that West Virginia's explicitly articulated goals and its carefully crafted plan can be powerful in affecting student learning. Such a tight match between the assessment tools and the instructional strategies should produce higher achievement scores.

Match Between Goals and Instructional Strategies

When the National Council of Teachers of Mathematics approved the new math standards in 1989, it set into motion a radical push for teachers to align their instructional strategies with the constructivist principles outlined in the standards and the subsequent documents. Lecture methods were no longer suitable if teachers believed that students should learn mathematics in an active way, allowing them to construct their own understanding. Leah McCoy (1996) conducted a meta-analysis of 65 studies looking at programming languages and student skills. She concludes, "Logo programming, particularly turtle graphics at the elementary level, is clearly an effective medium for providing mathematics experiences" (¶ 22). Yet having access to the computer and the software is not sufficient for learning. McCoy notes that most studies included the recommendation that "the teacher be involved in planning and overseeing the Logo experiences to ensure that students discover and understand the target concepts" (¶ 22).

Research by Min Liu and Keith Rutledge (1996) explored the affective realm, relating computer apprenticeship to student achievement. They compared two high school classes in a high minority, inner city school; approximately 60% of the population were considered "at-risk." The control group was an in-tact computer class (*n* = 22) learning to use specific programs and the treatment group (*n* = 24) was engaged in a multimedia design project. Lin and Rutledge quote literature on the importance of motivation's role in learning and student achievement. They concluded that, "the 'learner-as-designer' environment described here had a positive impact on

the at-risk high school students. As a result of participating in this project, the students showed a significant growth in their value of intrinsic goals" (p. 31). Observations about the students working during their lunch time, and before and after school demonstrate their motivation for the project. The study, however, did not attempt to determine how much learning could be attributed to the technology itself or to other components of the project; for example, students were creating for a "real audience"—a local Children's Museum. In the words of one of the museum's representatives, "I'm ecstatic with their work. Their work is excellent" (p. 42). The goal in this project was to engage students in digital apprenticeship and to observe the outcome on student work. The teacher did not lecture on how graphic designers work but varied the pedagogy to provide the potential for real audiences, a series of working artists, and ongoing support. Teaching within a computer design environment might feel risky for educators used to more traditional modes, and it necessitates a change in instructional strategies.

Some complexity resides in defining what constitutes technology integration. Is a lecture using presentation software substantially different from the exact same information delivered via overhead transparencies? A teacher unable to deliver a coherent explanation will not find her inability miraculously cured by PowerPoint. A lesson in which a student spends an hour on the Internet finding the latitude and longitude of his town shouldn't count as "usefully integrating technology" when the information is accessible with a 30 second visit to an atlas. Simply because a student is using a computer doesn't mean that the trade-offs in time and money make it an appropriate use. Many would argue that a classroom management system which "rewards" students who finish their "regular work" by playing games (even basic skill games) does not constitute technology integration. Not only does such a management system encourage rushing other tasks, it promotes unhealthy competition for limited resources. For further discussion of the difficulties see Fouts (2000), Joy & Garcia (2000), Kirkpatrick & Cuban (1998) or Painter, (2001). All of these issues point to the need for further research.

In 1999 researchers examined Idaho's far-reaching computer infusion initiative by relating test score gains to technology use patterns and technology literacy along with five other

components. (The sample population was over 35,000 8th- and 11th-grade students). The study concluded, "There is a positive relationship between academic performance in core studies, language, math, and reading and the integration of technology in Idaho's K-12 schools" (as quoted in Fouts, 2000, p. 22). The notable findings relevant for educators were that the strongest technological predictors of achievement gains were the ability to choose the appropriate software tool, the amount of computer use at school, and exposure to Internet and E-mail use.

Professional Development

In addition to Wenglinsky's (1998) and Mann et al.'s (1999) findings mentioned earlier, a deeper look at their full studies reveals a strong message which is related less to the technology *per se* than to administrative support and intensive teacher training. "West Virginia spent roughly 30¢ of every technology dollar on training, ten times the national average for schools" (Mann et al., p. 16). A related finding was laid out in Wenglinksy's (1998) national study of NAEP data. "Teacher professional development in technology and the use of computers to teach higher order thinking skills were . . . positively related to academic achievement" (pp. 5-6). Affording administrative support requires that educators in policy-level positions have more theoretical and practical knowledge of instructional technology. This includes developing a system for measuring local success (Costa & Bobowick, 2001) and providing for staff development.

"Teacher expertise is the most important factor in determining student achievement," writes Linda Darling-Hammond (Darling-Hammond & Ball, 1997, ¶ 5). She supports her statement with numerous studies, highlighting one by Ronald Ferguson, which found that "teachers' expertise (as measured by teacher education, scores on a licensing examination, and experience) account for far more variation in students' achievement than any other factor (about 40% of the total)" (¶7). Given the prevalence of computers in schools (Sandham, 2001), it is truly surprising that teachers are not taught how to get the most out of them. A 1999 survey reported that only 29% of teachers had participated in more than 5 hours of professional development in technology curriculum integration in the past year (Fatemi, 1999). Nor can we expect the passing of time

14

(and subsequent retirement of untrained teachers) to be the panacea. Fatemi notes that "teachers who have been in the classroom 5 years or fewer are no more likely to use digital content than those who have been teaching for more than 20 years" (p. 35).

Maine data shows similar findings. In the fall of 2000 a survey was sent to all teachers in the state to ascertain their access to computers, and their professional and classroom use of computers (Eberle & Keeley, 2000). Interestingly enough, only 30% of all teachers used computers frequently for their own professional development. Overall, teachers in Maine possessed a limited repertoire of instructional applications; infrequent use of computerized problem solving, multimedia, or simulations were often reported. However, teachers do tend to employ computers on a daily basis to meet immediate needs, with 63.3% of teachers frequently creating materials on the computer, 54.9% communicating with colleagues, and 43.2% performing administrative work with computers. One of the more alarming findings, echoing the national data, was that "Younger teachers do not use computer applications more than more experienced teachers" (p. 4) thereby indicating that these trends may not change with fresh influxes of new teachers. Further study may show whether these results can be attributed to a dearth of newer technologies or whether teachers do not know how to (or see no reason to) integrate computer use into classroom activities.

Denton and Manus (1995) cite research that found teachers who have had in-service training more likely to use computers in instructional problem solving than teachers who haven't. They compared 3 years of standardized test data from eight schools and concluded that "academic performance . . . across years suggest that something is happening that is positive" but add that bold claims are not supported (p. 4).

Access and Placement of Technology

Too often access to computers is considered the primary measure of instructional technology. A student-to-computer ratio shouldn't be perceived as the bottom line in evaluating technology's impact on education. Access to computers is a necessary but not sufficient require-

ment for determining the impact on educational outcomes. If many of these computers sit in the back of a classroom rarely receiving an ampere of electricity, the potential for understanding the benefits or drawbacks in teaching and learning will remain unactualized. "It seems educators may be making more progress in providing access to technology than in figuring out how to use it as a learning tool" (Doherty & Orlofsky, 2001, p. 45).

Dale Mann (1999) headed a study that asked, under what conditions was technology effective in raising student achievement? A significant finding was that "students who had access to [the program's] computers in their classrooms (the 'distributed' pattern) did significantly better than students who were taught with [the program's] equipment in lab settings. They had higher gains in overall scores and in math" (p. 13). Ready access to computers ensured that students had the potential to use them more often, and that teachers self-reported having better skills in lesson planning, and delivering and managing instruction. The placement of computers in the classroom instead of in a separate lab configuration is noteworthy.

Education Week (Sandham, 2001, p. 87) reported that Maine is "just now laying the groundwork for its first statewide school technology push," referring to Governor King's Technology Endowment Fund (State of Maine), 2001. This initiative will fund a portable digital device for every seventh grader in Maine for the school year 2002-2003. While many Maine educators will disagree with the "just now" statement in light of the 6-year-old ATM initiative and the 6-year-old Maine School and Library Network, they may be interested to note that the article goes on to say that the results of recent surveys show "some of the poorest areas had some of the best access to technology" (p. 87). It remains to be seen if the critical next steps to make the best use of these resources will occur. Contemplating future research about technology's effect on student learning in Maine is exciting because of the statewide breadth of the initiative and the standardization of hardware and infrastructure forms. The former has the potential of providing a rich data set and the latter, serves to reduce one strand of complexity.

Conclusion

In the rush to be "Ready for the 21st Century," some districts may have been satisfied with a simple list of the equipment deployed in their classrooms. Never a viable measure of educational success, the number of machines, RAM sizes, or even megahertz, will no longer impress constituents. This is especially true now that the ongoing toll on the budget becomes more evident. Not only is it necessary to justify purchases, implementation strategies, and professional development with research data such as found above, but districts should be prepared to acknowledge legitimate concerns relating to technology use or abuse. As part of the local assessment systems, educators could proactively secure data regarding their students' achievement in relation to technology usage.

This examination of pertinent studies shows that computers and technology have the potential to be an important and viable component for increasing student learning. However, the mere presence and even simplistic use of computers alone is no panacea. On one hand, educators who decry the hegemony of print-based literacies (Papert, 1993; Russell, 1998; Tapscott, 1998) insist that the misalignment between culture-based media and schools serves to disengage our students. On the other hand, Theodore Roszak (1996) sounds a voice of reason: "People who recommend more computers for schools are like doctors who prescribe more medicine. What medicine? How much medicine? For what reason? The same questions apply to computers." It is mandatory that educators make the best possible decisions. Heather Kirkpatrick and Larry Cuban (1998) summarize that the research is inconclusive in several areas. Pressing questions still remain unanswered and point to a dire need for further research: "Can we reach our [educational] goals at less cost—without additional investments in technology? Will computers help create the type of students and citizens we seek?" (¶ 42).

The state of Maine is poised to invest substantially in educational technology. There will be professional development training opportunities offered by a variety of resources, but schools and districts will need to continue asking the hard questions (Maine Department of Education, 2001). Despite the problems with conducting and reading the research, Cherle Lemke notes,

"The future forms of learning technology are impossible to predict, but we can design them better based on the islands of research that help explain where we have been" (quoted in the preface of Mann et al., 1999, p. 3). The research that we *do* have indicates that explicitly articulating goals, closely matching these with the assessment tools and instructional strategies, and the absolutely essential need for staff development do produce positive results in student learning.

References

Alliance for Childhood (2000). *Fool's gold: A critical look at computers in childhood.* College Park, MD. Retrieved August 18, 2001, from http://www.allianceforchildhood.net/projects/computers/computers_reports_fools_gold_contents.htm

Atwell, N. (1998). *In the middle: New understandings about writing, reading, and learning.* Portsmouth, NH: Boynton/Cook.

Ayersman, D. J. (1996). Reviewing the research on hypermedia-based learning. *Journal of Research on Computing in Education, 28*(4), 500-525.

Baker, E. L., Gearhart, M., & Herman, J. L. (1994). Evaluating Apple classrooms of tomorrow. In E. L. Baker, & H. F. O'Neil, (Eds.). *Technology assessment in education and training* (pp. 173-197). Hillsdale, NJ: Erlbaum.

Beichner, R. L. (1994). Multimedia editing to promote science learning. *Journal of Educational Multimedia and Hypermedia, 3*(1), 55-70.

Calkins, L. M. (1994). *The art of teaching writing.* Portsmouth, NH: Heinemann.

Coley, R. J. (1997, September). Technology's impact [Electronic version]. *Electronic School.* Retrieved on September 23, 2001, from http://www.electronic-school.com/0099713.html

Costa, Sr., J. P., & Bobowick, E. (2001). Linking technology to educational improvements. In B. Kallick & J. M. Wilson, III (Eds.), *Information technology for schools: Creating practical knowledge to improve student performance* (pp. 33-42). San Francisco: Jossey-Bass.

Darling-Hammond, L., & Ball, D. L. (1997). *Teaching for high standards: What policymakers need to know and be able to do.* Retrieved November 3, 2000, from http://www.negp.gov/Reports/highstds.htm

Denton, J. J., & Manus, A. L. (1995). *Accountability effects of integrating technology in evolving professional development schools.* (ERIC Document Reproduction Service No. ED393443)

Doherty, K. M., & Orlofsky, G. F. (2001, May 10). Student survey says: Schools are probably not using educational technology as wisely or effectively as they could. *Education Week, 20*(35) 45-48.

Eberle, F., & Keeley, P. (2000, November). *Survey of computer use of Maine teachers: Sample results from a study of teacher use, application in the classroom and access to computers.* Augusta, ME: Maine Mathematics and Science Alliance.

Edwards, V. B. (Ed.). (2001, May 10). The new divides: Looking beneath the numbers to reveal digital inequities [Special Issue: Technology Counts 2001]. *Education Week, 20*(35).

Fatemi, E. (1999, September). *Building the digital curriculum.* Retrieved November 24, 2000, from http://www.edweek.org/sreports/tc99/articles/summary.htm

Finkelman, K., & McMunn, C. (1995). *Microworld as a publishing tool for cooperative groups: An affective study* (Report # 143). Charlottesville: University of Virginia, Curry School of Education. (ERIC Document Reproduction Service No. ED384344).

Fouts, J. T. (2000, February). *Research on computers and education: Past, present and future.* Bill and Melinda Gates Foundation. Retrieved October 28, 2001, from http://tlp.esd189.org/images/TotalReport3.pdf

Joy, E. H., & Garcia, F. E. (2000). Measuring learning effectiveness: A new look at no-significant-difference findings. *Journal of Asynchronous Learning Network, 4*(1). Retrieved October 28, 2001, from http://www.aln.org/alnweb/journal/Vol4_issue1/joygarcia.htm

Healy, J. M. (1998). *Failure to connect: How computers affect our children's minds—and what we can do about it*. New York: Simon & Schuster.

Henry, T. (1999, February 28). Educator questions computers' educational value. *USAToday.* Retrieved August 18, 2001, from http://www.usatoday.com:80/life/cyber/tech/cta931.htm

Kafai, Y. B. (1995). *Minds in play: Computer game design as a context for children's learning.* Hillsdale, NJ: Erlbaum.

Kirkpatrick, H., & Cuban, L. (1998, Summer). Computers make kids smarter—Right? *TECHNOS Quarterly, 7*(2). Retrieved October 16, 2001, from http://www.technos.net/journal/volume7/2cuban.htm

Kulik, J. A. (1994). Meta-analytic studies of findings on computer-based instruction. In E. L. Baker & H. F. O'Neil, Jr. (Eds.), *Technology assessment in education and training* (pp. 9-33). Hillsdale, NH: Erlbaum.

Kulik, C. C., & Kulik, J. A. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior, 7,* 75–94.

Kulik, J. A., Kulik, C.-L. C., & Bangert-Drowns, R. L. (1985). Effectiveness of computer-based education in elementary schools. *Computers in Human Behavior, 1,* 59-74.

Liao, Y-K. C. (1998). Effects of hypermedia versus traditional instruction on students' achievement: A meta-analysis [Electronic version]. *Journal of Research on Computing in Education, 30*(4), 341-360.

Liu, M., & Rutledge, K. (1996, April). *The effect of a "learner as multimedia designer" environment on at-risk high school students.* Paper presented at the annual meeting of the American Educational Research Association, New York. (ERIC Document Reproduction Service No. ED394509). Later published in *Journal of Educational Computing Research* (1997) *16,*145-177.

Lundeberg, M. A., Coballes-Vega, C., Standiford, S. N., Langer, L., & Dibble, K. (1997). We think they're learning: Beliefs, practices, and reflections of two teachers using project-based learning. *Journal of Computing in Childhood Education, 8*(1), 59-8.

Maine Department of Education. (2001, September 25). *Maine Learning Technology Endowment.* Retrieved October 16, 2001 from http://www.state.me.us/mlte/

Mann, D, Shakeshaft, C., Becker, J., & Kottkamp, R. (1999). *West Virginia story: Achievement gains from a statewide comprehensive instructional technology program.* Milken Family Foundation. Retrieved August 27, 2001, from http://www.Mff.org/publications/publications.taf?page=155

McCoy, L. P., (1996). Computer-based mathematics learning [Electronic version]. *Journal of Research on Computing in Education, 28*(4), 438-461.

Painter, S. R. (2001). Issues in the observation and evaluation of technology integration in K-12 classrooms. *Journal of Computing in Teacher Education, 17*(4), 21-25.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer.* New York: HarperCollins.

Postman, N. (1992). *Technopoly: The surrender of culture to technology.* New York: Random House.

Repman, J., Weller, H. G., & Lan, W. (1994). Impact of social context on learning in hypermedia-based instruction. *Journal of Educational Multimedia and Hypermedia, 2*(2), 283-298.

Riddle, E. M. (1995). *Communication through multimedia in an elementary classroom* (Report # 143). Charlottesville: University of Virginia, Curry School of Education. (ERIC Documentation Reproduction Service No. ED384346)

Roschelle, J. M., Pea, R. D., Hoadley, C. M., Gordin, D. N., & Means, B. M. (2000). Changing how and what children learn in school with computer-based technologies. *The Future of Children, 10*(2), 76-97.

Russell, G. (1998). Elements and implications of a hypertext pedagogy. *Computers and Education, 31,* 185-193.

Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). Teaching with technology: Creating student-centered classrooms. New York: Teachers College Press.

Sandham, J. L. (2001, May 10). Across the nation. *Education Week, 20*(35), 67-105.

Schacter, J. (1999, June). *Impact of educational technology on student achievement: What the most current research has to say.* Milken Family Foundation. Retrieved August 27, 2001, from http://www.mff.org/publications/publications.taf?page=161

Sivin-Kachala, J., & Bialo, E. R. (1994). *Report on the effectiveness of technology in schools, 1990-1994*. Washington, DC: Software Publishers Association.

Sivin-Kachala, J., & Bialo, E. R. (1999). *1999 Research report on the effectiveness of technology in schools* (6th ed.). Washington, DC: Software Publishers Association.

Smith, F. (1986). *Insult to intelligence: The bureaucratic invasion of our classrooms.* Portsmouth, NH: Heinemann.

State of Maine. (2001, January). *Final Report of the Task Force on the Maine Learning Technology Endowment.* Augusta, ME: Office of Policy and Legal Analysis, Maine State Legislature.

Stoll, C. (1999). *High tech heretic: Reflections of a computer contrarian*. New York: Random.

Tapscott, D. (1998). *Growing up digital: The rise of the net generation*. New York: McGraw-Hill.

Tierney, R. J., Carter, M. A., & Desia. L. E. (1991). *Portfolio assessment in the reading-writing classroom.* Alexandria, VA: ASCD.

Turner, S. V., & Dipinto, V. M. (1992). Students as hypermedia authors: Themes emerging from a qualitative study. *Journal of Research on Computing in Education, 25*(2), 187-199.

Weller, H. G. (1996). Assessing the impact of computer-based learning in science. *Journal of Research on Computing in Education, 28*(4), 461-485.

Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics* (Report No. BBB27038). Princeton, NJ: Educational Testing Services. (ERIC Document Reproduction Service No. ED425191)

Wiggins, G., & McTighe, J. (1998). *Understanding by design.* Alexandria, VA: ASCD.