Designing A Study of the Effectiveness of Education Technology

Background Material for the First Meeting of the Technical Working Group

November 20-21, 2002

Mark Dynarski
Margaret Honey
Doug Levin

Questions

Which types of technology should be studied?
Which types of schools and students?
Which subject areas?

Issues

Breadth of technology coverage and design rigor
Measuring effects of technology using test scores or other assessments
Focus on high quality of implementation or on average quality
Select existing interventions or implement promising ones

Background

The No Child Left Behind legislation calls for a study of the effects of educational technology, using "control groups or control conditions," which are the hallmarks of an experiment (P.L. 107-110, sec. 2421(a)). The call for a landmark, rigorous study is consistent with other current efforts to expand the use of scientifically based methods in education research.

Designing such a study is a significant undertaking. No study of education technology has used experimental methods on a large scale. Important considerations must be addressed: how the study's questions should be focused, how to structure the design for measurement and resource efficiency, and how to collaborate with schools and districts. Rapid innovations in computing technology, changes in the education policy context created by No Child Left Behind itself, and the goal of ensuring that knowledge from the study is immediately useful for schools and teachers contribute to the challenges.

Several of the study's key parameters are implied by the legislation (see box, next page). The legislation indicates that the study's final report is due to Congress by April 1, 2006. With the 2002-2003 school year for the design, the 2003-2004 school year for site recruitment and implementing the evaluation, the 2004-2005 school year for random assignment and for follow-up, a follow-up period of one school year fits within the schedule. Moreover, the legislation calls for studying the effects of educational technology on student academic achievement, and on the "conditions and practices" that increase achievement, increase teachers' effective use of technology, and enhance learning environments and opportunities. The focus on academic achievement narrows the study's range of outcomes to be investigated, while the focus on studying conditions and practices under which technology if effective widens the study's range to include investigating relationships between impacts and implementation and context.

The background material presented here discusses important questions that the design effort faces. It also presents information about how education technology currently is used at various grade levels and the installed based on technology, and a brief summary of the research on the effectiveness of technology. Volumes could be written about how technology currently is used in schools and what the research evidence indicates about its effectiveness. We provide a cursory treatment of the issues in the interest of providing a starting point for discussion.

What Is the Study About?

A wide range of questions can be asked about the effects of educational technology, but not all of them can be answered by a single study, even if it is large. Narrowing the range of questions the study will address is a crucial early step.

The broad mandate implied by the study's legislative mandate already has been narrowed by ED to focus on the effects of technology *use*. Focusing on technology use, rather than availability, narrows the study in an important way to an examination of the interactions between technology, teachers, and students.

From *No Child Left Behind (P.L. 107-110)*

SEC. 2421. NATIONAL ACTIVITIES.

(a) STUDY- Using funds made available under section 2404(b)(2), the Secretary —

(1) shall conduct an independent, long-term study, utilizing scientifically based research methods and control groups or control conditions —

(A) on the conditions and practices under which educational technology is effective in increasing student academic achievement; and

(B) on the conditions and practices that increase the ability of teachers to integrate technology effectively into curricula and instruction, that enhance the learning environment and opportunities, and that increase student academic achievement, including technology literacy;

(2) shall establish an independent review panel to advise the Secretary on methodological and other issues that arise in conducting the long-term study;

(3) shall consult with other interested Federal departments or agencies, State and local educational practitioners and policymakers (including teachers, principals, and superintendents), and experts in technology, regarding the study; and

(4) shall submit to Congress interim reports, when appropriate, and a final report, to be submitted not later than April 1, 2006, on the findings of the study.

Focusing on technology use still leaves open the issue of what the technology is being used *for*. The wide range of technology applications includes such simple activities as learning to type on a computer keyboard or using the Internet to look up the meanings of words, to such complex applications as virtual simulations. Appealing to the need for improving student achievement helps narrow the range of technology applications to be considered: the applications should be those that can logically be linked to enhanced achievement. However, student achievement is itself a broad concept that leaves content areas to be considered. Should the learning outcomes be limited to such core content areas as reading, math, and science? Or should the areas be expanded to include diverse outcomes—for example, understanding the world of work or making presentations using PowerPoint©? The strong focus of No Child Left Behind suggests limiting the range to core content areas; but the decision ultimately needs to be made during the design study.

Another question the design needs to consider is, "used *for whom?*" In selecting interventions to study, the study needs to consider the types of schools and students being served by the technology application. For example, technology applications that support students with particular learning issues, such as students having difficulty learning to read or students learning English as their second language, may merit special consideration. Socioeconomic levels are another factor to consider. High-poverty schools have traditionally been a concern for federal education policy; thus, technology applications that emerge from high-poverty schools or that show the most promise for being effective in these schools may merit greater attention. Given this focus, examining the effects of interventions that currently operate only in high-income schools probably would raise questions about the study's policy relevance and may be inconsistent with the objectives of the No Child Left Behind Act.

Finally, the design needs to consider whether to examine the effects of how technology is currently used in schools, or whether it should examine the effects of how technology *could be* used in schools. The first approach measures the effects of technology in actual practice; the second measures the effects of approaches or techniques that may not be widely used in schools but may show great promise, analogous to testing medical treatments in clinics before the treatments are used in general practice. These approaches are not exclusive, so combining them would be possible. The issue of setting up "clinical trials" of technology applications in pilot schools may require a trade-off with other policy considerations. For example, the study could use a clinical-trial approach but only high-income school districts may agree to participate in setting up the technology application to be studied. In this case, the merits of being able to measure the effects of the application may be viewed as more important than the concern that the effects were generated in a high-income district rather than a low-income district.

Technical Considerations in Designing a Study

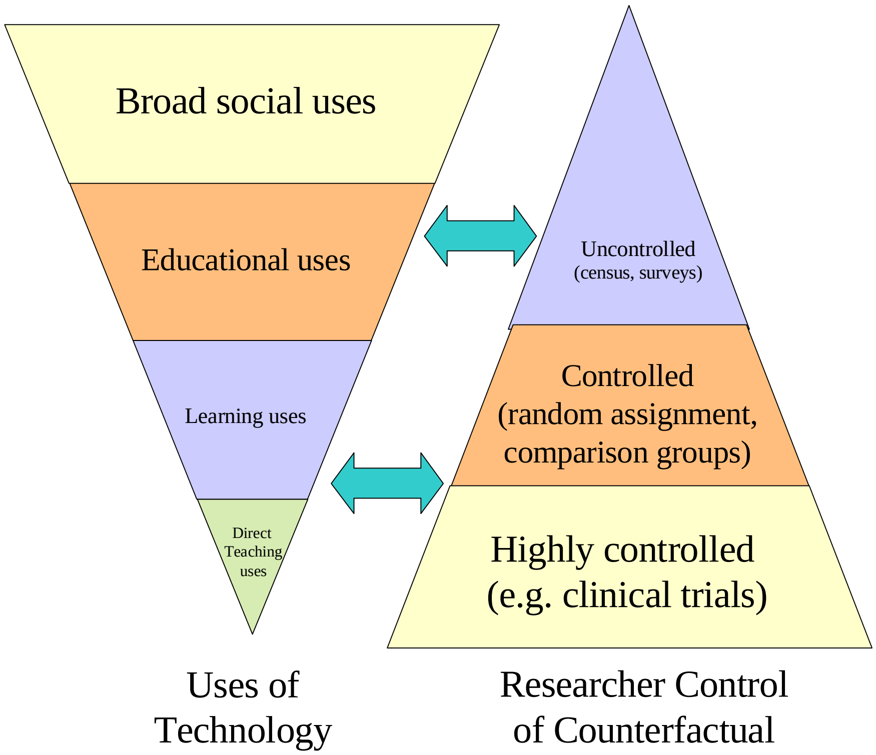
No better approach than random assignment has yet been devised for measuring the causal effects of interventions. However, designing a random-assignment study of technology interventions means grappling with the broad issue of how best to set up the *counterfactual*, which is what would have happened to intervention students if they had not received the intervention. Measured effects are the differences between outcomes of two groups, one affected by the intervention, the other affected by factors that exclude the intervention but that can include a wide variety of other technology- and school-related factors. A design has more power when the contrast between the intervention and the counterfactual is greatest, but often these conditions apply only for interventions not yet in widespread use and therefore not yet entailing substantial expenditures of public resources (see figure).

For example, an intervention that uses Web-based technology to access particular kinds of learning resources may be implemented in a setting where most students can access nearly the same resources from computers in their homes or elsewhere in the community. In this setting, the intervention's ability to generate impacts when the control group also can access the technology would be problematic, but a negligible measured impact would not mean the intervention was not effective, only that the intervention's effects were measured using a weak contrast. A stronger contrast would mean testing the intervention in a setting where control group students are not likely to also have access to the same resources.

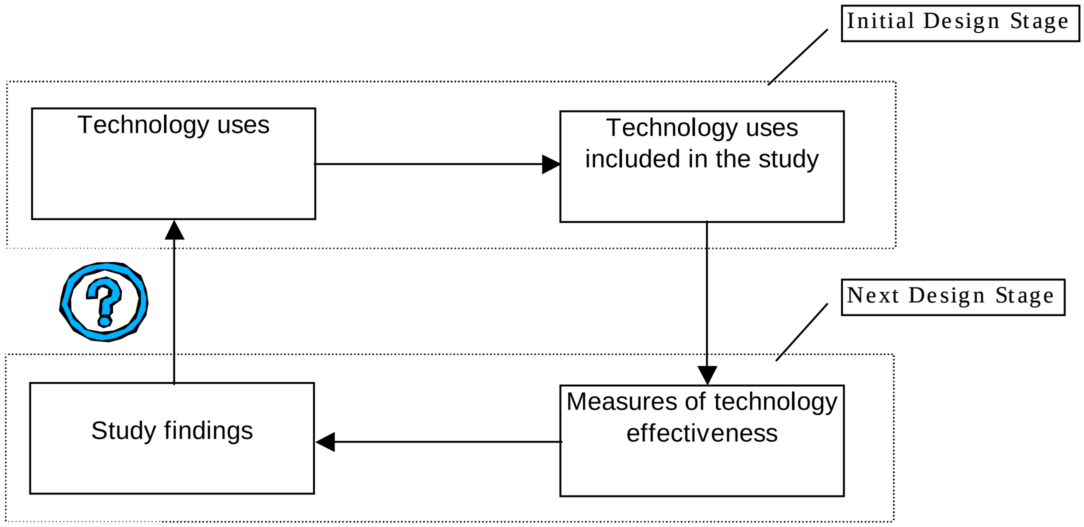
The nature of the counterfactual is related to the issue of determining appropriate sample sizes, so that the study will have a reasonable chance of measuring effects to an acceptable degree of statistical precision. Generally, the more sample units that are included in a study, the greater its ability to detect small effects. However, if the nature of a particular question requires the study to assign clusters of students to the intervention and control groups, such as students clustered in classrooms or in schools, the need for large samples can quickly use up available resources.

Statistical power considerations also apply to studying interventions that may be implemented differently by teachers and schools—a consideration that probably includes most education programs. Studying an intervention in only one school or district creates the possibility that effects measured in that one site are aberrant or exceptional. For example, if only one site in the sample implements a particular intervention, the study would have no means of assessing the extent to which its effects may vary under different conditions of implementation. Having multiple sites (classrooms, schools, or districts) implementing an intervention is necessary to assess the variance of the effects and to relate the variance to conditions and practices.

Technology Applications and Controlled Studies



Appropriate outcome measures also are an issue for the study. The legislation requires the study to focus on student academic achievement as an outcome. However, technology may affect other important outcomes. One outcome could be higher future wages or earnings, but the study's time frame is too short to examine longer-term outcomes. Another outcome may be improved computer literacy skills, and research has found that computer skills are related to success in the labor market. Assessing computer skills is a difficult task, as assessments have not been as fully developed as other assessments. Another outcome could be social competencies such as the ability to work in teams (related to project learning or to group efforts in using technology for learning). In considering the study design, outcomes to include in addition to test scores or grades will be an important consideration.



The Inferential Problem in Selecting Technology Uses

Identifying Technology Approaches

The study's objective of assessing technology's effectiveness leaves open the process of identifying particular technology approaches to be studied. Several processes can be considered and the most suitable one for the study will require more discussion. For example, selecting educational technology interventions could be based on:

- ***Sampling*** A general approach that is mostly of theoretical interest would be to randomly sample districts and schools and then measure the effects of how technology is used in each school. Results based on the sampling approach would have broad generalizability; however, the approach may conflict with the study's requirement to use a control group or controlled conditions, which may be infeasible in many of the sampled districts and schools. Because of its scale, a sampling approach also may require resources beyond what is available for the study. However, the sampling approach's broad generalizability makes it useful as a benchmark for more specific approaches noted below. Their narrower generalizability is visible against the backdrop of the sampling approach.
- ***Maturity of the approach*** Based on literature reviews, the study could identify approaches or models that are based on research, well defined, and have evidence to support their effectiveness. With obvious advantages to designing a rigorous study, this approach would lean the study toward older generations of educational technology.

- ***Prevalence*** Based on market research reports, the study could identify approaches that are widely used by educators in schools and classrooms today. The approaches may not be well specified or grounded in research, but a rigorous study would yield useful results to practitioners. Considering the rapid development of educational technologies, studying common interventions will, by the study's end, also lean the study toward older generations of educational technology, and would give short shrift to technology approaches that may be rapidly emerging and possibly show promise.

- ***Anticipated prevalence*** Based on predictions of technology developers, market researchers, and educational technology purchasers, the study could solicit nominations of technology interventions thought likely to be in widespread use by educators in the near future. While the quality of the predictions is risky, the study would be valuable to the extent that it predicts future technologies correctly and therefore provides useful information to practitioners faced with purchasing and implementation decisions at that time.

- ***Potential for impact.*** Based on predictions of educational technologists, researchers, and developers, the study could solicit nominations of technology interventions considered to be most likely to show impacts. This approach also has a prediction risk, and interventions that prove effective may be found to be unable to go to scale. However, the interventions might be found to result in substantial learning gains.

- ***Needs of students and teachers*** As contrasted to the above approaches, the study could look to the challenges facing K-12 schools today and identify interventions designed specifically to address them. For instance, the study could identify interventions designed to help young students learn to read better, or interventions designed to improve algebra skills, widely considered a gateway course for high school success.

Combinations of several approaches also can be considered. For example, the study could identify technology approaches that are prevalent and that have the potential for impact, or approaches that have the potential for impact and are anticipated to be prevalent. Regardless of the approach or combinations of approaches used, the design needs to consider the relationship between the technologies that are chosen and the broader question about the overall effectiveness of technology (shown as the question mark in the figure).

Key Issues

- *What are the core academic competencies that characterize student learning at different grade levels and across subject areas?*
- *What technologies might be used to support and enhance these competencies?*
- *What conclusions might be drawn from such an analysis about the most efficacious areas to focus on in a large scale, randomized study on technology's impact on student achievement?*

Uses of Technology

An important consideration in the design of a large scale study investigating technology's impact on student learning is to consider the ways in which technologies can be used to support academic learning at different grade-levels and across different content areas. To characterize the various ways in which technologies can be used across a students' academic lifecycle this paper does two things. First, in order to understand how particular technologies might support student learning, we briefly characterize the different types of technology applications that exist. Second, we draw on a both academic research and state and national standards documents to outline the major academic milestones that students are expected to accomplish at elementary, middle and high school levels and discusses some of the ways in which technologies might be used in the service of learning. For this paper, we have focused on mathematics and English language arts. These content areas are a critical focus for the No Child Left Behind Legislation and areas where there is a well-established research base on student learning.

Generally speaking, educational technologies fall into one of the following application "types":

- Drill and practice and educational games software like Reader Rabbit or Math Blaster;
- Productivity tools like Microsoft Word, ClarisWorks, Power Point, and Excel;
- Online, Web or CD ROM information resources;

- Cognitive tutors like Carnegie Learning's Algebra Tutor; or IBM's Watch Me Read early literacy program;
- Problem solving and simulation software like Oregon Trail, the Sim programs by Maxis (SimCity, SimEarth, SimAnt, etc.), Tom Snyder's Decisions, Decisions or Neighborhood Map Machine.
- Communication tools like email, online discussion centers, peer review sites, etc.
- Multimedia authoring programs like Kid Pix, Hyperstudio, Powerpoint, and html authoring tools.

With the growth of networked, multimedia technologies a number of technology-based learning programs now combine application types. Programs like Adventures in Supercomputing, for example, use a mix of technologies to introduce high school students to the field of computational science. Students engage in long-term projects that require them to pose hypotheses and devise methods and procedures for solving problems. They use a range of technology resources including online information, graphing and modeling tools, and email to communicate with professional scientists who serve as mentors. The goal behind such initiatives is to support students in solving complex problems employing methods, procedures, and strategies that mirror those used by discipline experts. While these kinds of programs tend to be more common in middle and high school mathematics and science curricula, initiatives like Maya Quest target social studies learning by having younger students work with multiple media to participate with scientists who are exploring the Yucatan where the ancient Maya lived.

The Education Market Research reports suggest that drill and practice and educational game software are used more at the elementary level where students need to acquire the core competencies associated with basic literacy and mathematics learning. At the middle and high school levels students are much more likely to be using productivity tools (Word, Powerpoint, Claris Works), as well as problem-solving software, and information resources. This breakdown makes sense given that younger students must master a range of foundational skills, whereas older students are developmentally ready for learning that offers more cognitive complexity as exemplified in the above examples.

In the remaining sections of this paper we briefly outline the core academic competencies that anchor student learning in two content areas – math, and English language arts.

Mathematics

A growing body of research suggests that understanding mathematics requires both conceptual and procedural fluency, and that these processes are deeply intertwined. Recent research on how children learn algorithms, for example, helps to explain the interdependence of conceptual and procedural knowledge (Hiebert, 1986; Rittle-Johnson & Siegler, 1998). Students who memorize facts or procedures without understanding often are unsure as to when or how to use what they know, and such learning is fragile (Bransford, Brown, and Cocking, 2000). Learning with understanding also makes subsequent learning easier. Mathematics makes more sense and is easier to remember and apply when students connect new knowledge to existing knowledge in meaningful ways (Schoenfeld, 1988). Well-connected, conceptually grounded ideas are more readily accessed for use in new situations (Skemp, 1976).

What this suggests with respect to the use of technology for mathematics learning is that a reliance on drill and practice or problem solving strategies in isolation from each other, may not be the most effective way to ensure lasting improvements in student learning and understanding.

At the earliest level of formal education (preK-2) young children begin to learn mathematical ideas that are related to patterns, shapes, and numbers. Drill and practice and game software can help students acquire and reinforce basic number facts, which paint and draw programs can be used to have students create shapes and explore patterns.

At the 3rd – 5th grade level students are building on their basic skills to engage in additive and multiplicative reasoning, they are exploring notions of equivalence, and working to establish computational fluency. They may begin exploring concepts of probability. Fractions, ratios, proportions are concepts that students are expected to master. Drill and practice and game software can again be used to consolidate students' computational skills, while using spreadsheets and graphing programs can help students investigate notions of equivalence, and graphic design tools can be used to explore fractions, ratio, and proportions.

During middle school students are expected to master the concepts associated with geometry and algebra. Problem solving software like the Geometer's Sketchpad can be used, along with cognitive Tutors like Carnegie Learning's Algebra program. Voyager Middle School Mathematics is another example of a technology-rich mathematics program that has students role-play professionals such as architects, population biologists and computer scientists who use mathematics to solve real-world problems. This program covers pre-algebra content, and makes use of problem solving software, graphing tools, and web-based resources to support student learning.

At the high school level, students are learning more sophisticated problem solving techniques and ways of analyzing data. Algebra and geometry are studied at more complex levels, along with statistics, probability and discrete math. Many students go on to higher-level math courses including calculus and trigonometry. Graphing calculators can be used to explore functions;

Spreadsheets and graphing programs to can support students understanding of more complex forms of data representation and analysis; digital visualization tools can be used to create and interpret large data sets, and programming tools can be used by students to build computational models.

English and Language Arts

Phonemic awareness, phonics, vocabulary development, reading fluency, and reading comprehension strategies are the building blocks of literacy instruction in early elementary school. There is little doubt that effective instruction in reading and language is fundamental to children's overall academic success. The skillful processing of text is an essential skill – one that directly impacts students' ability to learn across the curriculum. Studies reveal that children who were poor readers in grade three did not "catch up" to their normally achieving peers.1 Seventy-four percent of the students that were poor readers in grade 3 were poor readers in grade 9.2 The fact that academic success, as defined by high school graduation, can reasonably be predicted by level of reading skill at the end of grade three, underscores the critical importance of ensuring that all children learn to read in the early elementary grades.

A common misconception is that elementary school language arts instruction is adequate and sufficient to meet the more sophisticated and challenging reading tasks of the secondary curriculum. Elementary students must not only acquire the basic building blocks of early literacy – phonemic awareness, phonics, vocabulary, and fluency – but being able to comprehend

[1] Francis, Shaywitz, Stuebing, & Fletcher, 1996, Juel, 1998

[2]Francis, et al 1996

and extrapolate meaning from a text is critical to student success at middle and high school levels. Reading programs that teach reading only through basic skills rather than teaching students methods and strategies for understanding, interpreting, and relating text do not prepare students adequately for the more cognitively challenging tasks associated with reading at the middle and high school levels.

At the middle school level, researchers have begun to identify the effectiveness of literacy instruction that is an integral component of a comprehensive curriculum (Alvermann, 1988; Pearson, 1996). Most middle schools in the U.S., however, offer little or no systematic reading program, and those that do tend to offer it in the form of separate, corrective, or remedial classes rather than programs integrated into the curriculum (Irvin, 1990). Remedial reading classes are typically focused upon basic skills in reading and have been criticized for not addresses the need to teach critical thinking and higher-level comprehension skills (Greenleaf, Schoenbach, Cziko, & Mueller, 2001).

Middle and high school students face constantly increasing demands on their reading and writing skills: they are expected to comprehend more expository, rather than narrative material; to process more abstract concepts; and to read and write increasingly longer assignments (Irvin, 1990). Students are also required to interpret and understand texts in a more complex manner than elementary school students – whereas students "learn to read" in elementary school, students in middle school must "learn to read to learn" (Nelson and Herber, 1982).

Technologies can be used across the curriculum to support students' English Language Arts learning. At the early elementary level, drill and practice and game software can support students' in learning a range of basic literacy skill. Technologies can also support a wide range of expressive literacy skills – from creating simple storybooks using multimedia production programs to using word processing to create and edit written work. Unlike the domain of mathematics where there is quite a broad range of problem solving software, English language arts – particularly at middle and high school levels – is dependent on teachers using tools and resources to support literacy as part of existing curricula.

The Availability And Use Of Technology In K-12 Schools For Instruction

Empirical data about the installed based on technology in schools is useful for understanding the general context of technology interventions. Identifying particular technologies to study necessarily means making choices about what not to study, and a sense from the data about what is not being studied is useful information for the decision process.

Market data show that computers and the Internet are relatively common fixtures in schools. The availability of standalone instructional software varies by grade level, with generally more tool-based applications (such as word processing and spreadsheets) becoming increasingly more prevalent by secondary school. The use of the Internet is, by and large, not often required by teachers, but when it is used by students it is primarily used to assist with research for papers and projects. On average, teachers tend to report that they use software (including online resources) only a few times a month, favoring the use of textbooks, handouts, manipulatives, and workbooks.

According to Market Data Retrieval (2002), on average a computer is available for about every four students. Access to multimedia computers and Internet-connected computers is more limited. On average, almost six students share every computer connected to the Internet, and six students share every multimedia computer in the installed base.

Education Market Research (EMR) reports commonly available software and CD-ROM titles for instructional use (SIIA, 2002). Table1 shows the popularity of leading titles by grade level.

Quality Education Data has collected data on the use of the Internet for school (SIIA, 2002). The figure below presents the types of uses of the Internet employed by students. Of note, teachers reported to QED that Internet use was only required between 9 and 16 percent of the time, depending on the subject. That is, much student use of the Internet for school is at least partly optional.

Table 1
Leading Titles for Grades K-12

Grades K-2

Title	Publisher	Rank and % of Overall Sample
Kid Pix	Broderbund-The Learning Company/ Riverdeep	1st – 60.4%
Reader Rabbit	The Learning Company/Riverdeep	2nd – 60.4%
Printshop	Broderbund-The Learning Company/ Riverdeep	3rd – 51.5%
Hyperstudio	Vivendi Universal/ Knowledge Adventure	4th – 51.5%
Math Blaster	Vivendi Universal/ Knowledge Adventure	5th – 50.5%
AppleWorks/ ClarisWorks	Apple/Claris	6th – 49.5%
Oregon Trail	MECC- The Learning Company/Riverdeep	7th – 48.5%
Millie's Math House	Edmark/Riverdeep	8th – 48.5%
Accelerated Reader	Advantage Learning Systems	9th – 47.5%
Bailey's Book House	Edmark/Riverdeep	10th – 46.5%

Source: Education Market Research, *The Complete K-12 Report,* 2001

Grades 3-5

Title	Publisher	Rank and % of Overall Sample
Oregon Trail	MECC- The Learning Company	1st – 60.5%
Math Blaster	Vivendi Universal/ Knowledge Adventure	2nd – 57.3%
Hyperstudio	Vivendi Universal/ Knowledge Adventure	3rd – 54.8%
Kid Pix	Broderbund-The Learning Company/ Riverdeep	4th – 53.2%
Accelerated Reader	Advantage Learning Systems	5th – 50.8%
Microsoft Word	Microsoft	6th – 50.8%
Encarta	Microsoft	7th – 50.8%
Reader Rabbit	The Learning Company/Riverdeep	8th – 49.2%
Printshop	Broderbund-The Learning Company/ Riverdeep	9th – 49.2%
Grolier Encyclopedia	Grolier	10th – 49.2%

Source: Education Market Research, *The Complete K-12 Report*, 2001

Grades 6-8

Title	Publisher	Rank and % of Overall Sample
Microsoft Word	Microsoft	1st – 60.0%
Power Point	Microsoft	2nd – 58.3%
Encarta	Microsoft	3rd – 55.4%
Microsoft Office	Microsoft	4th – 54.9%
Printshop	Broderbund-The Learning Company/Riverdeep	5th – 49.1%
Oregon Trail	MECC- The Learning Company/Riverdeep	6th – 48.5%
Accelerated Reader	Advantage Learning Systems	7th – 48.0%
ClarisWorks	Claris	8th – 48.0%
Hyperstudio	Vivendi Universal/ Knowledge Adventure	9th – 47.4%
Grolier Encyclopedia	Grolier	10th – 47.4%

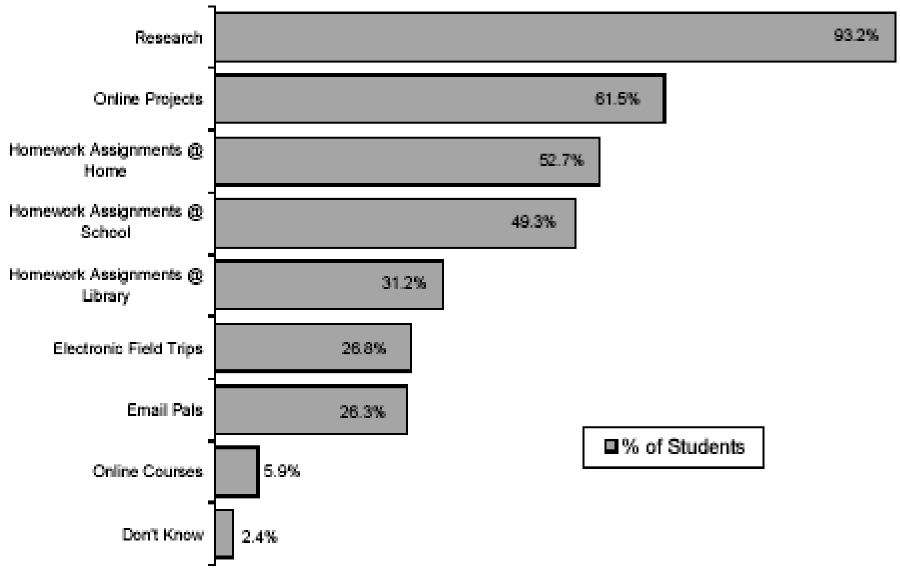
Source: Education Market Research, *The Complete K-12 Report*, 2001

Grades 9-12

Title	Publisher	Rank and % of Overall Sample
Microsoft Word	Microsoft	1st – 76.5%
Microsoft Office	Microsoft	2nd – 58.8%
Power Point	Microsoft	3rd – 53.9%
Microsoft Excel	Microsoft	4th – 50.0%
Encarta	Microsoft	5th – 45.1%
Printshop	Broderbund-The Learning Company/Riverdeep	6th – 36.3%
Adobe Photoshop	Adobe	7th – 31.4%
Grolier Encyclopedia	Grolier	8th – 29.4%
ClarisWorks	Claris	9th – 26.5%
Geometer Sketch Pad	Key Curriculum Press	10th – 21.6%

Source: Education Market Research, *The Complete K-12 Report*, 2001

Student Use of the Internet



Source: QED, *Internet Usage in Public Schools*, 2000

A 2002 study conducted by Mathew Greenwald & Associates of 1,000 randomly sampled National Education Association teachers from across the country provides some insight into the frequency of use of the specialized instructional software and CD-ROMs. Of note, this study places the frequency of technology use in context of the use of other instructional materials.

Frequency Of Instructional Material Use

	Sample	Every day	3-4/ week	1-2/ week to 1-2/ Month	Less often	Not available
Textbooks	National	47%	14	17	13	8
Handouts	National	32%	23	37	6	2
Manipulatives	National	30%	15	32	16	7
Workbooks	National	21%	10	24	29	17
Specialized instructional software, either on a computer or on-line	National	18%	9	37	25	11
CD-ROMS	National	14%	7	35	30	14
Audio recordings, including books on tape	National	9%	7	30	39	14
Original source materials such as newspaper clippings	National	4%	6	56	30	5
Slide, film or videotaped presentations	National	1%	3	58	30	7

Recent Studies of The Effectiveness Of Educational Technology Interventions For K-12 Students

The design effort also needs to consider the evidence that has accumulated about the effectiveness of various technology interventions. Studying an intervention for which research already has established its effectiveness would be an inefficient use of the study's resources.

Comprehensive reviews of the effectiveness of various educational technology interventions from 1996 to the present were identified through a literature search and the Internet. A total of 35 English-language reviews were obtained, including 9 quantitative meta-analyses. Four reviews were conducted in countries other than the U.S., including Australia, Canada, and the U.K. Reviews that sought primarily to characterize the field of educational technology research and development, as opposed to the effectiveness of educational technology interventions, were excluded from consideration. The accompanying table provides basic information on key characteristics of each of these reviews, including year of publication, type of interventions reviewed, academic subject matter, student population, and coverage of the literature (selective or systematic, including dates of coverage if available).

Taken together, the reviews suggest disjointed and contradictory findings with little meaningful accumulation of knowledge about the effectiveness of educational technology interventions on academic outcomes for K-12 students. More specifically:

- **Small number of studies meeting basic standards of research quality.**

  For instance, based on the application of minimum methodological criteria, Murphy *et al*. (2002) excluded 84 percent of the 195 experimental or quasi-experimental studies on the effectiveness of discrete educational software in reading and mathematics they had initially identified. The National Reading Panel (2000) found that fewer than 5 percent of studies identified on the effectiveness of instructional technology on reading met their substantive and methodological criteria.

- **Poorly defined or overly general conceptions of educational technology interventions.**

  Many reviews do not provide important detail on: (a) which technologies are employed, (b) how specifically they are employed, and (c) for what duration and frequency they are employed. In addition, most reviews do not provide a causal theory for why one might expect an improvement in academic outcomes due to the use of a specific educational technology intervention over typical classroom instruction or other instructional approach designed to affect the same outcome.

- **Little information reported about variations in implementation of educational technology interventions or the nature of the control conditions.**

  In the absence of this information, it is difficult to rule out alternate explanations for the outcomes of reviewed studies.

- **No sensitivity to (a) variations within and across academic content areas, (b) differences in grade level of students, and (c) differences in other student characteristics.**

  The effectiveness of specific educational technology interventions has been studied across a wide range of content areas, grade levels, and type of student. In characterizing its effectiveness, the majority of reviews, however, treat educational technology interventions as if they should uniformly influence academic outcomes, regardless of substantial variations in academic goals for different student populations. The lack of a causal theory for why one might expect such a generalized improvement in academic outcomes across content areas and student populations is notable.

- **Interventions discussed in reviews may not be typical of those used by schools.**

  While many reviews of K-12 educational technology interventions focus on studies conducted in school settings, they are insensitive to the prevalence of these interventions in practice. The study of educational technology interventions provides a number of challenges in this regard: (1) Both the quantity and variety of technologies in schools continue to increase; (2) Educational technology interventions are not typically stable over time (i.e., new versions of software replace older versions; more powerful computer processors come to market; multimedia and graphical displays increase in resolution and become more interactive; new tools obviate or change the patterns of use of old ones; etc.) (3) Up-to-date information on the prevalence of uses of specific educational technology interventions is not generally available; and (4) A substantial period of time—often stretching over years—is required to conduct and publish a single high-quality study.

- **Many reviews point out the need for a clear and systematic program of rigorous research to guide policy decisions.**

  Indeed, there is a growing body of related literature that offers suggestions on the specific priorities and foci of such a program of research.

KEY CHARACTERISTICS OF SELECTED REVIEWS: 1996-2002 (DRAFT)

Authors (Alphabetical, by Publication Date)	Interventions Reviewed	Subject Matter	Population of Study	Literature Coverage
		Publication Date: 1996		
Ayersman	Hypermedia-based learning	Various	K-16 students	Selective (unspecified dates)
Berson	Computer activities (including simulations, drill and practice, educational games, tutorials, database management, word processing and writing, and graphing)	Social studies	Unspecified	Selective (unspecified dates)
Fitzgerald and Koury	Computer-assisted instruction	Reading, writing, mathematics, social studies, science	K-12 students with mild and moderate cognitive, learning and/or behavioral disabilities	Selective (peer-reviewed, empirical studies from 1988-1995)
McCoy	Various computer-based activities (including programming, computer-assisted instruction, and tool applications)	Mathematics (compatible with constructivist framework of the NCTM standards)	K-16 students	Selective (unspecified dates)
Reed	Computer-based instruction (including the use of word processing software, modified word processing software, and composing process software)	Writing	K-16 students	Selective (unspecified dates)
Weller	Computer-based learning (including computer-assisted instruction, simulations, and microcomputer-based laboratories)	Science	K-16 students	Selective (peer-reviewed research from 1988-1995)
		Publication Date: 1997		
Christmann, Badgett, and Lucking	Computer-assisted instruction	Various	Secondary students	Systematic (1985-1995)
Christmann, Lucking, and Badgett	Computer-assisted instruction	Various	Secondary students	Systematic (unspecified dates)
Hanson et al.	Distance education	Various	Unspecified	Selective (unspecified dates)
		Publication Date: 1998		
Cuban and Kirkpatrick	Educational technology/computers	Various	Unspecified	Selective (unspecified dates)
Hennessy	Graphing calculators and portable (laptop) computers	Various (focus on mathematics and writing	Primary and secondary students internationally	Selective (unspecified dates)
Jones and Paolucci	Educational technology/computers	Various	Unspecified	Systematic (1991-1996)
Liao	Hypermedia (including interactive multimedia, multimedia simulators, and interactive videodiscs)	Various	Unspecified	Systematic (1986-1997)
Reeves	Media and technology	Various	Unspecified	Selective (unspecified dates)
		Publication Date: 1999		
Bennett and Lockyer	Computer-based technology (including hardware, software, and the Internet)	Various	K-12 students in Australia and internationally	Selective (unspecified dates)
Cavanaugh	Interactive distance education (including videoconferencing and online telecommunications)	Various	K-12 students	Systematic (1980-1998)
		Publication Date: 1999 (continued)		

KEY CHARACTERISTICS OF SELECTED REVIEWS: 1996-2002 (DRAFT)

Authors (Alphabetical, by Publication Date)	Interventions Reviewed	Subject Matter	Population of Study	Literature Coverage
Lee	Computer-based instructional simulation	Various	Unspecified	Systematic (unspecified dates)
Russell	Distance education (including various low- and high-technology approaches)	Various	Unspecified	Selective (1928-1998)
Statham and Torell	Technology (including hardware, software, and multimedia)	Various	Unspecified	Selective (unspecified dates)
Publication Date: 2000				
Fouts	Computers and related technology	Various	Unspecified	Selective (unspecified dates)
Hall et al.	Computer-assisted instruction (including drill and practice, strategy instruction, and simulation applications)	Reading	K-12 students with learning disabilities	Systematic (1980-1997)
National Reading Panel	Computer technology	Reading	PreK-12 students	Systematic (1986-1996)
Silvin-Kachala and Bialo	Educational technology	Various	Unspecified	Selective (late 1980s-2000)
Wartella et al.	Interactive media (including video games, CD-ROMs, the Internet, and other computer software)	Unspecified	Children (of unspecified ages)	Selective (unspecified dates)
Publication Date: 2001				
Lou et al.	Effects of social context (I.e., small group versus individual learning) when students learn using computer technology	Various	Unspecified	Systematic (unspecified dates)
MacArthur et al.	Technology	Literacy (reading and writing)	Students with mild disabilities (of unspecified age/grade/disability type)	Selective (unspecified dates)
Publication Date: 2002				
Andrews et al.	Information and communication technologies	Literacy (English language)	5 to 16 year olds internationally	Systematic (post-1990)
Bayraktar	Computer-assisted instruction	Science	Secondary and college students	Systematic (unspecified dates)
Blok et al.	Computer-assisted instruction	Reading	Young children (various ages/grades)	Systematic (1990-2000)
Liu et al.	Computer use	Second and foreign language learning	Unspecified	Systematic (1990-2000)
Lowe	Computer-based education	Various	Unspecified	Systematic (1980-1998)
Marshall	Technology-based instruction (including television, multimedia, and computer technologies)	Various	Unspecified	Selective (unspecified dates)
Murphy et al.	Discrete educational software	Reading and math	PreK-12 students	Systematic (1993-2000)
Ringstaff and Kelley	Computer-based technology	Various	K-12 students	Selective (1993-2002)
Ungerleider and Burns	Information and communication technologies	Various	K-12 students internationally	Selective (unspecified dates)

Bibliography

Market Data Retrieval (2002). Highlights from Technology in Education 2002. Available online at: http://www.schooldata.com/publications3.html

Software and Information Industry Association (SIIA) (2002). 2002 Education Market Report: K-12. Washington, DC: Author.

Mathew Greenwald & Associates (2002). National Education Association 2002 Instructional Materials Survey: Report of Findings. Washington, DC: National Education Association and the Association of American Publishers. Available at: http://www.publishers.org/press/pdf/2002%20Instructional%20Materials%20Report.pdf

Andrews, R., Burn, A., Leach, J., Locke, T., Low, G., Torgerson, C. (2002). A systematic review of the impact of networked ICT on 5-16 year olds' literacy in English (EPPI Centre Review). *Research Evidence in Education Library*, 1. London: EPPI Centre, Social Science Research Unit, Institute of Education.

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

Bayraktar, S. (2002). A Meta-analysis of the effectiveness of computer-assisted instruction in science education. *Journal of Research on Technology in Education* 34:3, 173-188.

Bennett, S., and Lockyer, L. (1999). *The impact of digital technologies on teaching and learning in K-12 education: Research and literature review—Final report*. Prepared for Curriculum Corporation. University of Wollongong, Australia. Available at: http://www.thelearningfederation.edu.au/repo/cms2/tlf/published/3295/docs/lit_res.pdf

Berson, M. (1996). Effectiveness of computer technology in the social studies: A Review of the literature. *Journal of Research on Computing in Education*, 28:4, 486-499

Blok, H., Oostdam, R., Otter, M. and Overmaat, M. (2002). Computer-assisted instruction in support of beginning reading instruction: A review. *Review of Educational Research*, 72:1, 101-130.

Cavanaugh, C. (1999). *The effectiveness of interactive distance education technologies in K-12 learning: A meta-analysis.* Tampa, FL: University of South Florida. (Eric Document Reproduction Service No. ED430547).

Christmann, E., Badgett, J., and Lucking, R. (1997). Progressive comparison of the effects of computer-assisted instruction on the academic achievement of secondary students. *Journal of Research on Computing in Education* 29:4, 325-337

Christmann, E., Lucking, R., and Badgett, J. (1997). The effectiveness of computer-assisted instruction on the academic achievement of secondary students: A meta-analytic comparison between urban, suburban, and rural educational settings*.* *Computers in the Schools,* 13:3/4, 31-40.

Cuban, L., and Kirkpatrick, H. (1998). Computers make kids smarter—right? *Technos*, 7:2, 26-31.

Fitzgerald, G. and Koury, K. (1996). Empirical advances in technology-assisted instruction for students with mild and moderate disabilities, *Journal of Research on Computing in Education*, 28:4, 526-553.

Fouts, J. (2000). *Research on computers and education: Past, present, and future*. Prepared for the Bill and Melinda Gates Foundation. Available at: http://www.esd189.org/tlp/images/TotalReport3.pdf

Hall, T., Hughes, C., and Filbert, M. (2000). Computer-assisted instruction in reading for students with learning disabilities: A research synthesis. *Education & Treatment of Children*, 23:2, 173-.

Hanson, D., Maushak, N., Schlosser, C., Anderson, M., Sorensen, C., and Simonson, M. (1997). *Distance education: Review of the literature* (2^{nd} ed.). Washington, DC: Association for Educational Communications and Technology.

Hennessy, S. (1998). *The potential of portable technologies for supporting graphing investigations*. Institute of Educational Technology, Open University, UK. Available at: http://education.leeds.ac.uk/research/groups/cssme/Hennessy.pdf

Jones, T. and Paolucci, R. (1998). The learning effectiveness of educational technology: A call for further research. *Educational Technology Review, 9:10-14*

Lee, J. (1999). Effectiveness of computer-based instructional simulation: A meta-analysis. *International Journal of Instructional Media*, 26:1, 71-85.

Liao, Y. (1998). Effects of hypermedia versus traditional instruction on students' achievement: A meta-analysis. *Journal of Research on Computing in Education* 30:4, 341-356.

Liu, M., Moore, Z., Graham, L., and Lee, S. (2002). A look at the research on computer-based technology use in second-language learning: A review of the literature from 1990-2000. *Journal of Research on Technology in Education* 34:3, 250-273.

Lou, Y., Abrami, P., and d'Apollonia, S. (2001). Small group and individual learning with technology: A meta-analysis. *Review of Educational Research*, 71:3, 449-521.

Lowe, J. (2002). Computer-based education: Is it a panacea? *Journal of Research on Technology in Education* 34:2, 163-171.

MacArthur, C., Ferretti, R., Okolo, C. and Cavalier, A. (2001). Technology applications for students with literacy problems: A critical review. *The Elementary School Journal*, 101:3, 273-301.

Marshall, J. (2002). *Learning with technology: Evidence that technology can, and does, support learning*. Washington, DC: Cable in the Classroom. Available at: http://www.ciconline.com/uploads/CIC_REPORT.pdf

McCoy, L. (1996). Computer-based mathematics learning, *Journal of Research on Computing in Education*, 28:4, 438-459.

Murphy, R., Penuel, W., Means, B., Korbak, C., Whaley, A., and Allen, J. (2002). *E-DESK: A review of recent evidence on the effectiveness of discrete educational software*. Prepared for the Planning and Evaluation Service, U.S. Department of Education. Menlo Park, CA: SRI International, Inc. Available at: http://www.fas.org/learn/Task%203%20Final%20Draft%20Report.pdf (with appendices at: http://www.fas.org/learn/Task%203%20Appendix%20B.pdf and http://www.fas.org/learn/Task%203%20Appendix%20C.htm)

National Reading Panel (2000). Chapter 6: Computer technology and reading instruction. In *Report of the National Reading Panel: Teaching children to read—Report of the subgroups.* Prepared for National Institute of Child Health and Human Development, U.S. Department of Health and Human Services. Available at: http://www.nichd.nih.gov/publications/nrp/report.htm

Reed, W.M. (1996). Assessing the impact of computer-based writing instruction. *Journal of Research on Computing in Education* 28:4, 418-437.

Reeves, T. (1998). *The impact of media and technology in schools*. A Research Report prepared for The Bertelsmann Foundation. Available at: http://www.athensacademy.org/instruct/media_tech/reeves0.html

Ringstaff, C., and Kelley, L. (2002). *The learning return on our educational technology investment: A review of findings from research*. San Francisco, CA: WestEd RTEC. Available at: http://www.WestEd.org/online_pubs/learning_return.pdf

Russell, T. (1999). *The no significant difference phenomenon: A comparative research annotated bibliography on technology for distance education*. Montgomery, AL: International Distance Education Certification Center.

Silvin-Kachala, J. and Bialo, E. (2000). *2000 research report on the effectiveness of technology in schools.* (7th ed.). Washington DC: Software and Information Industry Association.

Statham, D., and Torell, C. (1999). *Technology in public education in the United States*. Prepared for Texas Education Agency, Division of Textbook Administration. Available at: http://www.tea.state.tx.us/Textbooks/archives/litrevie.htm

Ungerleider, C., and Burns, T. (2002). *Information and communication technologies in elementary and secondary education: A state of the art review*. Prepared for 2002 Pan-

Canadian Education Research Agenda Symposium "Information Technology and Learning," April 30-May 2, 2002. Montreal, Quebec. Available at: http://www.spectrainteractive.com/pdfs/ICTInSchoolsReview.pdf

Wartella, E., O'Keefe, B., and Scantlin, R. (2000). *Children and interactive media: A compendium of current research and directions for the future*. New York, NY: Markle Foundation. Available at: http://www.markle.org/news/digital_kids.pdf

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