SIIA

Software & Information Industry Association

2000 Research Report on the Effectiveness of Technology in Schools: Executive Summary

The Promise and Challenge of Educational Technology

Two decades of practical experience with educational technology and a decade of research on it permit us to make several assertions with a fair degree of certainty:

- Technology can improve teaching and learning, but just having technology doesn't automatically translate to better instructional outcomes. Whether a given school experiences the potential benefits of technology depends on the software it chooses, what students actually do with the software and computer hardware, how educators structure and support technology-based learning and whether there is sufficient access to the technology.

- In order to promote desired instructional outcomes, software must be effectively designed. What we know about effective software design has grown to the point that electronic publishers can create and educators can choose quality software.

- There isn't one "right" type of software nor one "right" way to use technology. Rather, the software and the way it is used instructionally must match the school's learning and teaching goals and must be appropriate for the specific students who will use it.

- If we want students to engage in appropriate technology-based learning experiences and if we want educators to successfully structure and support these experiences, then teacher professional development and support is essential.

- Making appropriate school- and district-level decisions about desired uses of educational technology, software selection, professional development and support, hardware and technology infrastructure, and overall implementation requires a well-conceived planning process.

- Computer and communication technologies continue to change—and educational technology tools and their implementation must continue to evolve as well. With the ever-accelerating rate of technological change, new opportunities are continually arising for positive, innovative uses of technology in education. This underscores the need for *ongoing* educational technology planning, evaluation and refinement of the current implementation, and professional development and support.

An Area of Significant Change and Growth

As we move into the 21st century—and our third decade of using microcomputers and related information technologies for instructional purposes—the education market has transformed from a stand-alone desktop world to a Web-connected world. In this new age of computing, the opportunities and challenges are great for educators, publishers, and hardware vendors alike. During the last decade, U.S. K-12 schools have approximately *tripled* their spending for instructional technology, from $2.1 billion in 1991-1992 to a projected $6.2 billion in 1999-2000, not including E-rate funding (Quality Education Data, 1999). Similar increases have occurred in higher education, with estimated total technology expenditures of $2.7 billion in 1999-2000 (Market Data Retrieval, 1999).

About This Report

In 1990, the Software Publishers Association (SPA) published its first "Report on the Effectiveness of Microcomputers in Schools." (SPA and IIA merged in 1999 to become the Software & Information Industry Association.) In that report, numerous research studies supporting the use of technology as a valuable tool for learning were described. These studies indicated that the use of technology as a learning tool could make a measurable difference in student (1) achievement, (2) attitudes and (3) interaction with educators and other students. The evidence suggested that positive effects of technology were dependent upon the subject area, characteristics of the student population, the teacher's role, student grouping decisions, the design of the software and the level of access to technology. Since then, research documenting the effectiveness of educational technology has continued to grow and become more detailed. This seventh edition of the report continues the tradition of summarizing leading research on the effectiveness of technology in K-12 and higher education and on the effectiveness of specific software design characteristics.

This report, commissioned by the Software & Information Industry Association (SIIA) and conducted by an independent educational technology consulting firm, Interactive Educational Systems Design Inc. (IESD), summarizes educational technology research from the late 1980s through 2000.

This report is based on 311 research reviews and reports on original research projects, from both published and unpublished sources. Of these 311 studies, 135 were published in professional journals and 56 were doctoral dissertations. The 311 studies were chosen from an original set of more than 3,500.

Research studies summarized in this report feature one or more of the following as part of their methodology:

- A technique for synthesizing and analyzing data from many different studies (meta-analysis)
- Comparison of the use of technology to traditional instructional methods
- Comparison of different software designs
- Comparison of the use of technology by student populations with different learning characteristics
- Comparison of the use of technology under different learning environment conditions
- Analysis of student performance data (e.g., test results, performance assessments)
- Analysis of classroom observation and surveys of educators and students

Studies were not included for a variety of reasons. Some were weak in methodology (e.g., comparisons of a computer-based instructional treatment to no alternative treatment) and others addressed topics not of concern in this report (e.g., critiques of typical research methods; research on the attitudes of student teachers; research on the design of the physical layout of technology-rich classrooms).

The report is divided into three sections:

- Effects of technology on student achievement
- Effects of technology on student self-concept and attitude about learning
- Effects of technology on interactions involving educators and students in the learning environment

Subsections that are new to this seventh edition of the report include the following:

- Effects of technology on student achievement
  - Large-scale technology implementations
  - Curriculum areas and student achievement
    - Technical training
  - Software design characteristics and student achievement
    - Amount of practice
    - Pedagogical agents
    - Learner support in foreign language learning
    - Graphs in mathematics instruction
    - Spoken narration, text, and sounds with graphics
    - Multiple representations of arithmetic problems
  - Instructional decisions and student achievement
    - Exploratory vs. confirmatory approach to computer simulation
    - Task structure when students search the Internet
    - Medium for administration of assessment
- Effects of technology on interactions involving educators and students in the learning environment
  - Effects of technology on teacher-student interactions and educators' instructional behavior
    - Technology in a project-based learning environment
    - Internet use

A comprehensive bibliography of the research cited is also included.

Conclusions

Technology is making a significant positive impact on education. The findings of greatest importance in the research reviewed for this report include the following.

General

- The specific student population, the software design, the educator's role, how the students are grouped, the preparedness of the educator and the level of student access to the technology influence the level of effectiveness of educational technology.
- Educators are an essential element in the effectiveness of technology.
- Software is effective because it allows individual learner traits and multiple pathways to learning (e.g., text, graphics, speech) to be taken into consideration when software is being designed and used.
- Effectiveness of educational technology depends on a match between the goals of instruction, characteristics of the learners, the design of the software and technology implementation decisions made by educators.
- Students of teachers with more than 10 hours of training significantly out-performed students of teachers with 5 or fewer training hours.

Positive Effects of Technology on Student Achievement

Educational technology has demonstrated a significant positive effect on achievement. Positive effects have been found for all major subject areas, in preschool through higher education and for both regular education and special needs students. More specifically:

- Large-scale, statewide implementations of educational technology (in West Virginia and Idaho) have been correlated to gains in standardized test scores.
- In studies focusing on reading and language arts, technology has been shown to provide a learning advantage in the areas of phonological awareness (awareness of the structure of sounds in a language), vocabulary development, reading comprehension and spelling. Furthermore, there is evidence that students who use word processing software in combination with carefully sequenced instruction in the writing process or writing tools with built-in guidance in the writing process improve their writing significantly more than students without access to such tools, as do students who write to a real audience via the Internet or e-mail.
- Technology has been used effectively to support mathematics curricula that focus on problem solving and hands-on, constructivist, experiential activities. Students participating in such technology-supported learning experiences have demonstrated superior conceptual understanding of targeted math topics than students receiving traditional instruction.
- Studies focusing on science education suggest the benefits of simulations, microcomputer-based laboratories, video to anchor instruction to real-world problems, and software that targets students' misconceptions.
- A learning advantage has been found when students have developed multimedia presentations on social studies topics.
- Kindergartners who have used technology have benefited in areas such as improved conceptual knowledge, reading vocabulary, reading comprehension, and creativity.
- Educational technology has significant positive effects on achievement for special needs populations. Speech recognition is an especially valuable compensatory tool for the learning disabled.
- Interactive video is especially effective when the skills and concepts to be learned have a visual component and when the software incorporates a research-based instructional design.
- Use of online telecommunication for collaboration across classrooms in different geographic locations can improve academic skills.

- Using the Internet to provide college students with supplementary instructional resources can benefit their academic performance.
- Use of distance learning has been shown to be as effective as instruction that takes place locally.

Positive Effects of Technology on Student Motivation and Self-Concept

- Educational technology has been found to have positive effects on student attitudes toward learning and on student self-concept. Students felt more successful in school, were more motivated to learn and had increased self-confidence and self-esteem when using computer-based instruction. The evidence of these effects is the strongest for:
  - Language arts and writing instruction
  - Mathematics instruction
  - Science instruction
  - Telecommunication technology, including the Internet
  - Video technology
- Educational technology has significant positive effects on student attitudes for special need populations.

Effects of the Teacher's Role and Instructional Decisions

- The teacher's role is of primary importance in creating an effective, technology-based learning environment—an environment that is characterized by careful planning and frequent interaction among students and the teacher.
- Teacher professional development and decisions about how computers are to be used in instruction may matter more than how often technology is used.
- Students trained in collaborative learning on computer in small groups had higher student achievement, higher self-esteem and better attitudes toward learning than students working individually. The positive effects of collaborative learning were especially pronounced for low ability students and for female students.
- Expanding student responsibilities through a learner-as-multimedia-designer environment can positively impact student attitudes.
- Decisions about the choice of medium when assessing student performance should reflect students' experience writing on the computer. Testing students by having them write by hand has been shown to result in an underestimation of their writing abilities if they are accustomed to writing on computer. However, multiple choice tests administered via computer and using pencil and paper have been shown to yield similar results.

Effects of Specific Software Design Features

Specific software design elements have been shown to have a positive impact on student achievement and on student motivation and self-concept. Several research-based suggestions follow.

- Offering students some control over the amount and sequence of instruction, including options for student review of material, can result in higher achievement and better student attitudes toward learning than having the software control all instructional decisions. However, low-achieving students and students with little prior content

knowledge are likely to require more structure and instructional guidance than other students are. When students have a high need to learn, this may nullify the impact of the level of learner control.

- In tutorial and practice software, programs with feedback providing knowledge of correct responses were found to be superior to programs that require students to keep answering until they achieve a correct response. Furthermore, feedback that identifies *why* a response is wrong was found to be more effective than feedback that only identifies *what* was wrong.

- Software that includes embedded cognitive strategies provides students with a learning advantage. Helpful cognitive strategies include:
    - Repetition and rehearsal of content
    - Specific note-taking techniques
    - Paraphrasing
    - Outlining
    - Cognitive mapping or diagramming
    - Drawing analogies and inferences
    - Generating illustrative examples
    - Having students explain their steps in solving problems
    - Specific techniques for reading in the content areas
    - Using pictorial information

- Students can benefit academically from software with embedded conceptual change strategies — sequences of instruction that move students from their faulty preconceptions to a more accurate understanding of the concepts involved.

- Instructional scaffolding—gradually decreasing the level of help available and/or gradually increasing the complexity of the task—can be effective in improving student achievement.

- Animation and video can enhance learning when the skills or concepts to be learned involve motion or action.

- Animation accompanied by spoken narration is generally superior to animation accompanied by explanatory text. When including narration, additional extraneous audio (e.g., music, sound effects) should be avoided.

- Still graphics can enhance learning when the concepts or skills to be learned have a visual component but do not involve motion or action.

- Content-related graphics (both static and animated) and video can help improve student attitudes and motivation in mathematics and science.

- Students using hypermedia software can benefit from an interface that includes a navigation map that shows the links among the various screens of information and the hierarchical structure of the information. It is also advisable to make the entire hyperspace to which students will eventually have access fully transparent while limiting their access to what is currently instructionally appropriate.

- Foreign language students can benefit from presentation of video segments with captioning (i.e., subtitles in the target language) and from access to native language translation when reading text-and-graphics dialogues in the target language. These design features are likely to make a difference for ESL students as well.

- Recent research additionally suggests possible benefits from inclusion of the following

software design characteristics (subject to further exploration and confirmation):

- Providing sufficient practice
- Stating objectives
- Advanced organizers in simulations
- Pedagogical agents that communicate with a human voice in a personalized dialogue with the student
- Graphs in mathematics instruction
- Multiple representations of concepts
- Dynamic visualization of abstract concepts
- Motivational contexts, such as story, game, and fantasy elements
- Multiple window presentation options (overlapping vs. tiled windows)

Effectiveness of Interactions Involving Educators and Students in the Learning Environment

- Introducing technology into the learning environment has been shown to make learning more individualized and student-centered, to encourage cooperative learning and to stimulate increased teacher-student interaction. Technology has been used successfully to support constructivist, inquiry-based and project-based instructional methods.
- Specific characteristics of the learning environment help to maximize the benefits of educational technology:

  - District-level involvement and the leadership of a school-level computer coordinator are key factors in developing a school environment conducive to effective use of technology.
  - Educators are more effective after receiving extensive training in the integration of technology with the curriculum.
  - Exemplary computer-using educators benefit from a social network of other computer-using educators at their school.
  - Exemplary computer-using educators typically have smaller class sizes and more funds available for software acquisition.
  - Educators should carefully plan, and actively participate in, learning activities that incorporate tool software. Before students use database software independently, they should be given search strategy training.
  - Educators should offer students self-directed learning experiences and activities that encourage self-expression.
  - Students benefit from personal interaction among class members.
- Courses for which computer-based networks were used increased student-student and student-teacher interaction increased student-teacher interaction with lower-performing students, and did not decrease the traditional forms of communication used. Many students who seldom participated in face-to-face class discussions become more active participants online.
- Classroom connectivity to the Internet was found to be the best predictor of teachers' professional use of the Internet. Furthermore, classroom connectivity in general and, more specifically, connectivity with four or more computers were found to be

important factors in predicting whether teachers directed student research involving the Internet.

- When upper elementary students use the Internet to conduct research, they tend to spend more of their time browsing rather than conducting carefully planned searches. Teachers are advised to provide a variety of support, possibly including "natural language" search engines, guided practice in conducting searches, broadly defined research tasks, and instruction in identifying and using relevant source material. These findings may apply to older students with limited Internet research experience as well.

- Small group collaboration on the computer is especially effective when students have received training in the collaborative process. However, there are trade-offs in deciding whether students should work individually or collaboratively:
    - Students who worked in groups were found to interact more with their fellow students (including cognitive and positive social interactions), to use more appropriate learning strategies, and to persevere more on assigned instructional tasks.
    - Students who worked individually at the computer were found to spend more time actually engaged with the software and to complete their tasks more quickly, but they needed more help from the teacher.

- Greater student cooperation, sharing and helping behaviors has been shown to occur when students use computer-based learning in which students compete against the computer rather than against each other.

    - University and inservice teacher training provides educators with greater comfort in using computers, an increased desire to use computers and an understanding of how to integrate software into the classroom curriculum.

- Preservice teachers have successfully used communication technologies such as e-mail, news groups, and listserv mailing lists to exchange ideas on instructional issues. Preservice teachers who do this over several weeks have been shown to make greater gains in self-efficacy and confidence in their teaching abilities than teachers without access to such tools.

- Positive changes in the learning environment brought about by technology are more evolutionary than revolutionary. These changes occur over a period of years, as educators become more experienced with technology. Long-time computer-using teachers tend to make changes in the learning environment generally related to a constructivist teaching approach.

This report provides software developers and publishers with research that will enable them to improve educational technology so that it continues to have a significant positive impact on student achievement, self-concept and motivation and on the interactions in the learning environment for students of all ages, capabilities, socio-economic backgrounds and areas of interest. The research reviewed in this report aims to help educators make effectual educational decisions as they incorporate technology-based learning experiences into the curriculum, increase student achievement and motivation in a variety of subject areas and consider advantageous software design characteristics when selecting software.