From PLATO to Podcasts:

Fifty Years of Federal Involvement in Educational Technology

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The views expressed in this paper are those of the author.

Summary

This paper aims to inform future federal education policy by examining the federal government's role in educational technology over the past 50 years. The paper analyzes five programs that had significant federal involvement through either direct legislation or significant funding:

- Sesame Street educational television
- The PLATO computer-based instructional system
- Computer-assisted instruction (CAI) at Stanford
- The Star Schools distance learning program
- The E-Rate initiative to build telecommunications infrastructure

The analysis focuses on three main questions:

- What effect has the use of technology had on student achievement?
- What effect has educational technology had on the achievement gap and the issue of equity in general?
- What were the intended and actual effects of the programs?

The answers to these questions will help determine the federal government's impact in educational technology during the past half-century and aid in reassessing its role going forward.

The evaluation literature on these programs, which was more extensive for some programs than for others, suggests five general observations:

1. The five programs succeeded in achieving their goals.
2. The most successful programs had an extensive federal role in the design as well as the implementation stages.
3. Legislative language that has promoted the use of particular technologies has often led to the introduction of outdated equipment and methods due to the rapid evolution of technology.
4. Without the involvement of the federal government, educational technology would not have reached disadvantaged students and communities, including rural areas and inner cities, to the extent it has.
5. Although educational technology has been shown to produce learning gains as measured by standardized tests, it has done so only in a supplementary role and in certain subject areas.

In light of these observations, the following recommendations are offered to policymakers to guide the future federal role in this area:

1. More funds should be made available in the form of grants to researchers to develop new technologies. Unlike funding that is set aside for specific products or services, research grants will allow for more flexibility and innovation.

2. The federal government must ensure that enough resources are available not just for the development of new technologies but also for implementation and other services associated with the products.

3. To ensure an equitable allocation of advanced technologies, which are often unaffordable in early stages, federal policymakers should provide supplementary funding to underprivileged areas that lack adequate resources.

Introduction

Technology has served as a valuable tool in education for centuries. From the abacus used by ancient civilizations to Gutenberg's printing press, advancements in technology have transformed instruction and learning in many ways. Over the past 100 years, communication technologies, in particular, have been touted as instruments to revolutionize education. Ever since the development of the radio, proposals have been put forth to use these technologies to deliver education (OTA, 1982).

In spite of these early developments, only during the past 50 to 60 years has educational technology, as we know it today, assumed a considerable role in American schools. Interestingly, significant involvement by the federal government in this field commenced roughly during the same time period.

From the National Defense Education Act (NDEA) of 1957, which was enacted following the Soviet launch of Sputnik, to the No Child Left Behind Act, technology has been a key component of every major federal education law of the last six decades. Today, federal investments in educational technology have ballooned to more than a billion dollars (Software & Information Industry Association, n.d.).

The costs of personal computing have significantly diminished since its inception, and unit costs continue to decrease year after year. This scenario, combined with the emergence of the Internet (another brainchild of government funding), is opening up avenues in education that might only have been fantasies a few decades ago. Moreover, today there is a strong support for technology in all aspects of society, as evidenced by rhetoric that includes phrases such as "21st century skills." Given this status quo, funding for technology in education is likely to increase. Before the federal government commits any more resources to educational technology, it is important to ask how this growing federal involvement has affected American education. Some might argue that technology has changed drastically over the past several decades and that the effects of older technology on education are not worth examining. But while the technology might have changed—PDAs now versus videodiscs two decades ago—the reasons behind their implementation have largely remained the same, and valuable lessons can be learned from their successes and failures.

This paper attempts to evaluate the effects of federal initiatives in educational technology in elementary and secondary education over the past half-century. While federal resources have been diluted across many programs, this paper focuses on the few initiatives in which the federal role was substantial and integral. The findings from this paper have implications for reevaluating the federal government's role in educational technology and the best approaches for incorporating this very important area of education into future federal education legislation.

Organizing Frames

In order to understand the impact of the federal government's role in educational technology, this paper examines five initiatives in educational technology:

- Sesame Street, one of the first programs to promote television as a learning tool in the home
- Programmed Logic for Automatic Teaching Operations, better known an PLATO, an early system of computer-based instruction
- Computer-assisted instruction at Stanford and its offshoot, the Computer Curriculum Corporation (CCC)
- Star Schools, a program to develop a technology infrastructure for distance learning
- E-Rate, which encouraged the spread of telecommunications technology for learning

While other programs may be considered by some to be more relevant and historic, these five were selected for several reasons.

First, each initiative represents the major educational technology development of one of the past five decades—PLATO, which had its origins in the 1950s, CAI in the 1960s, Sesame Street in the 1970s, Star Schools in the 1980s, and E-Rate in the 1990s. Hence, not only do these initiatives provide a nearly complete picture of the federal government's imprint, but they also illustrate how that involvement has evolved over the years. Any attempt to evaluate the federal role in technology in education would be incomplete if any of these efforts were absent. Second, these programs pertain to elementary and secondary education; in fact, all but PLATO were designed primarily to benefit pre-college students. Third, the federal government was a major player in initiating or sustaining these programs. This stands in stark contrast to many other educational technology programs in which federal grants constituted only a small piece of the funding pie. Fourth, these programs together cover a wide range of uses of educational technology in the 21st century, including technology as a learning tool at home, computer-assisted instruction and its variations, and distance learning and associated infrastructure.

An increase in student achievement was the primary yardstick used to gauge the success of these programs. For E-Rate and Star Schools, however, this yardstick does not apply to the same degree, since the main purpose of these two programs was to help develop infrastructure rather than provide instruction, as the other programs were designed to do. An attempt has also been made to access the programs' impact on the equitable distribution of technology. In addition, the paper looks at whether the intended goals of the programs were achieved and whether the programs led to unintended or unforeseen side effects, both positive and negative.

Some of the programs, while initially sustained by government funding, were later absorbed by the private sector. In those cases, the evaluations discussed in this paper are limited to the time when the federal government played an active role, and subsequent developments and impacts of the programs while under private ownership are not included in analyzing the success or failure of the program.

Sources

Three reports from the now defunct Congressional Office of Technology Assessment (OTA)[1] served as guiding sources for this paper: *Information Technology and Its Impact on American Education* (1982); *Power on! New Tools for Teaching and Learning* (1988); and *Linking for Learning: A New Course for Education*. These reports provided the necessary background for this paper and helped identify the landmark initiatives. Studies evaluating the programs were primarily found on the ERIC and JSTOR[2] databases.

Federal Role and Motivations for Educational Technology

Before this paper gets into the details of the various programs, it is essential to consider the arguments for and against a federal role in technology in education. Such a reflection will help determine whether educational technology, even if found to have great benefits, should be spearheaded by the federal government through a national policy.

First, an active federal role is needed to ensure equitable access to new and existing technologies for all. Costs of new technologies are exorbitant, and decreasing tax revenues are limiting local funds for innovation in education. Federal participation can reduce the gulf between the technology haves and have-nots.

Second, a workforce with advanced technological literacy is needed for most of the jobs in a 21st century economy. Only the federal government has the resources to overcome obstacles and prepare the nation as a whole to participate in highly skilled occupations.

[1]The Congressional Office of Technology Assessment, which existed from 1972-1995, provided comprehensive, technical analyses on various public policy issues for Congress. It influenced many items of legislation and helped foster channels of communication between policymakers and members of the scientific, technical, and business communities.

[2]ERIC, the Education Resources Information Center, is an online digital library of education research and information sponsored by the Institute of Education Sciences (IES) of the U.S. Department of Education. JSTOR is an online archive that preserves academic journals in digital and print formats.

Third, in the early stages of most educational technologies the potential market is small, and long-term funding from state and local authorities is uncertain. This uncertainty may prevent private entities from making a commitment to research and development. Without the federal government taking the lead and providing development funds, high-risk, state-of-the-art technologies are less likely to be developed.

Fourth, efforts on a national level would bring expertise and provide feedback from a much bigger group. Such an undertaking has the potential to develop and nurture better technologies than most states are capable of doing on their own.

There are also certain downsides to an active federal role. First, active federal involvement would limit choices available in educational technology by eliminating incentives for the private sector to participate in this field. This could mean less innovation.

Second, any proposal for technology in education at a national level could be a burden on local authorities. They may be forced to use technologies prescribed by the federal government instead of acquiring or developing tools that best suit local needs.

Third, on a related note, federal involvement may make school districts dependent on federal funds and provide them with less flexibility. Schools could be forced to change curriculum and instructional practices as a result of federal participation. These modifications may cause unnecessary disruptions and even more problems if federal funding is discontinued.

Fourth, a significant federal undertaking may give the impression that technology is a panacea. This view may cause education authorities to follow the federal lead and shift away from a tried-and-tested way of traditional education.

It is also worth considering the motivations behind using technology in education. In the 1950s and 60s, technology was seen a vehicle for improving student achievement. This was especially true in the years immediately following the Soviet Union’s launch of the Sputnik satellite, when policymakers and the public felt that American students were not adequately prepared to compete with the Soviets. However, the early initiatives focused only on mathematics, reading, and science—areas considered essential for gaining technological supremacy. Technology was also seen as an inexpensive way to provide instruction to the increasing number of students enrolling in all levels of education in the post-war period.

About thirty years ago, information technology began to take root in various sectors of the American economy. Around this time, educational technology began to be viewed as a means to provide the skills and technological know-how necessary to hold jobs in the information economy. This perspective is reflected in many federal educational technology initiatives of this period.

Another motivation behind technology use has been to narrow the achievement gap. Supplementary instruction provided through tools such as CAI was seen as a feasible option to improve the performance of disadvantaged students.

Limitations

The reader should keep in mind that this paper attempts to assess the impact of federal involvement in educational technology by looking at research data, primarily those that pertain to effects on student achievement. This means that the analysis does not address various other contributions of the federal government of no less importance—such as acting as a trailblazer in bringing educational technology to schools or using the bully pulpit and the power of the purse to guide states' education policies—that have not been the focus of research studies. Moreover, federal leadership exists in concert with other political structures and is often not quantifiable. These facts make it difficult to discern the extent of such a federal role.

Also, the effects of the five programs on achievement are measured by student performance on standardized tests. In no way do these tests provide a complete picture of student abilities. Nevertheless, research in educational technology has often relied on test scores as a metric. As a result, the findings of this paper may not fully reflect the impact of educational technology on student learning.

This paper is a historical analysis rather than an evaluation of the current state of educational technology. Although an examination of powerful recent innovations, such as online schools, administrative technology for data processing and analysis, and computer-based testing, could provide useful insights, the research literature on these innovations is not as extensive as that on the programs described in this document. This lack of data limits one's ability to assess the true impact of current programs. Given this state of affairs, any attempt to derive conclusions on the efficacy of recent technologies would take away greatly from the research value of this paper.

Although waiting for the results of research studies may seem overly prudent, given the rapid pace of innovation in educational technology, the alternative would be worse. Picking educational technologies based on their short-term impact can have unintended long term consequences for a generation of learners.

The paper also evaluates the impact of the federal role solely by analyzing programs when they were under federal control and therefore does not address the impacts of certain technologies emerging from subsequent research years later. It is often difficult to pinpoint the effects of a particular past component (federal leadership) on a technology or program that has undergone several revisions since its inception. Given this complexity, this analysis is limited to the time when the five programs were funded or guided by the federal government.

The next sections of this paper look at the five programs in detail.

Sesame Street: Television as a Learning Tool at Home

For several years, education researchers and practitioners have focused on the importance of learning that takes place outside the classroom (U.S. Department of Education, 1997; Tolbert & Theobald, 2006). One reason for this focus has been the realization that there is limited time for teacher-student interaction in classroom settings. Additionally, research has shown that helping students understand knowledge, and not merely conveying it, is essential if students are to apply what they have learned to other settings. Based on these facts, some researchers have emphasized the need for students to assimilate knowledge at home via informational technologies (Dede, n.d.). Before these steps are taken, it is important to ask whether learning at home is at least as effective as learning through traditional means. The case of Sesame Street, a program that used television as a medium of instruction, provides some valuable insights.

Background

Sesame Street was one of the first large-scale educational programs designed primarily for preschool children. It was conceived at a critical time. Research into early childhood development had just demonstrated the importance of preschool years in laying a foundation for later intellectual growth. At the same time, educators had taken notice of the increasing amount of time that young children, particularly those from disadvantaged backgrounds, spent watching television, and had expressed concern about the types of programs available and their impacts. Moreover, survey data showed that 90% of all families with incomes below $5,000 owned at least one television set and that children from those families watched an estimated 54 hours of television per week (OTA, 1982). Educators and psychologists believed that the best way to narrow the achievement gap was to intellectually stimulate disadvantaged children at an early age (Cooney, 1970).

The priority target group for Sesame Street was disadvantaged children from the inner cities. A full year was devoted to pre-production. Child development specialists, television experts, educators, animators, psychologists and filmmakers were brought together to develop and test programming and to come up with instructional goals for the program. These goals for concepts to be taught were divided into three broad categories: i) symbolic representation, i.e. letters, numbers and geometric forms; ii) problem solving and reasoning, including identification of different objects and pictures and comprehension of relational concepts; and iii) the natural environment, including geographical locations, objects, people, and other features indigenous to them, as well as the family and home environment (Cooney, 1970).

These instructional goals were conveyed through learning units comprised of stories, skits, games, and songs, and into 30- and 60-second animation sequences analogous to advertisements on commercial television. The first regular programming of Sesame Street began on November 10, 1969.

Federal Involvement and Funding

The federal role in Sesame Street took shape predominantly through funding, which was by no means small. The combined budget for the first two years (the preproduction year and the first year of broadcasting) of Sesame Street was $8 million. Fifty percent of this sum was paid by the U. S. Office of Education, and the remainder was funded primarily by the Carnegie and Ford Foundations (OTA, 1982). After the fledgling stage, the budget was $6 million for fiscal year 1971. The Office of Education was again the major funding source, followed by the foundations and the Corporation for Public Broadcasting. The huge success of the first season attracted new support from the business sector—Quaker Oats and General Foods—to supplement the regular shows with weekend and evening broadcasts (Cooney, 1970). Altogether, between 1968 and 1980, Children's Television Workshop, Sesame Street's parent company, received $46.3 million from the U.S. Office of Education.

Impact

Sesame Street is viewed as a broadcasting success. Only a few years after its inception, the viewing audience for the program spiked to 7 million. After being on the air for just one year, the show won the Peabody award for meritorious service to broadcasting in 1970 (Panos, 1981). By 1980, Sesame Street was one of the most viewed programs on public television and had a larger viewing audience among the 2- to 5-year-old demographic than any commercial television program. Studies noted that 80 to 90% of children in low-income neighborhoods watched the show (OTA, 1982). It has also been aired in eight languages and more than fifty countries.

Analysis

Most of the studies of Sesame Street have primarily addressed student achievement, as evidenced through performance on standardized tests. A few, however, did look at qualitative measures. The two most comprehensive studies of Sesame Street were undertaken by Samuel Ball and Gerry Ann Bogatz for Educational Testing Service (ETS).

The ETS evaluation of the first year of Sesame Street (Ball & Bogatz, 1970) gave a ringing endorsement for the program and its achievement of stated goals. This study was conducted on a group of 943 children in five locations around the country—Boston, Durham, Philadelphia, Phoenix, and rural northeastern California. The sample included disadvantaged children from the inner city, advantaged suburban children, children from rural areas, and disadvantaged Spanish-speaking children. The study reached three primary findings.

First, there was a positive correlation between Sesame Street watching and learning; i.e., the pre-test to post-test gains on a test designed to measure achievement of the program's curriculum goals were higher for those who watched the program more. Moreover, this finding was true across age, sex, geographic location, socioeconomic status, mental age, and viewing environment. Three-year olds learned the most in terms of test gains, and 5-year-olds learned the least. The learning effects were particularly noteworthy for disadvantaged students. While these students had a very low starting score on the skills measured, those among them who spent a considerable time watching the show scored better on post-tests than their middle-class counterparts who only watched a little.

Second, the skills that were best learned were the ones that were closely aligned with the learning goals of Sesame Street. According to a content analysis of the program, the most time was devoted to letter-related skills. Children showed the most improvement in areas of letters and numbers.

Third, adult supervision was not necessary for children to learn the material, as evidenced by the comparable gains of students viewing the show at home and at school under teacher supervision.

This finding was particularly striking at the time, in that 80% of 3- and 4-year children did not attend any kind of school.

The evaluation of the second year of Sesame Street (Ball & Bogatz, 1971) measured more complex skills than the first-year study. Out of the 29 goal areas tested, 13 showed a strong, positive influence by the program, and 10 others showed positive, less definite gains. No negative effect, specifically non-viewers outperforming viewers, was observed. Hence, for two years in a row, Sesame Street had a measurable, educational impact. The second-year study also examined the program's impact using the less objective measure of teacher rankings. According to teacher rankings, children who watched Sesame Street were better prepared for school than non-viewers. Moreover, the fear that the fast-paced television format of Sesame Street would cause students to lose interest in conventional classroom instruction turned out to be unfounded. The study also found that encouragement to view was an important factor affecting children's gains from watching the program. Attitude measurements, implemented in the second year of the program, revealed gains among at-home viewers in favorable attitudes toward school and toward people of other races. Additionally, even though Sesame Street never had gains in vocabulary as an objective, the second-year study suggests that the program did have a positive effect on viewers, as measured by the Peabody Picture Vocabulary Test (PPVT).

This finding was further confirmed by a study sponsored by the National Institute of Mental Health (Rice et al., 1990). This longitudinal investigation found that viewing Sesame Street had a positive impact on preschool children's vocabulary, again as measured by the PPVT. The effect was more pronounced in the 3- to 5-year-old group (the target audience of Sesame Street) than the 5- to 7-year-old group. The study also observed that other kinds of children's programs, such as cartoons, had no impact on the vocabulary of the sample of children. The results suggested that Sesame Street's impact on vocabulary development was independent of parent education, family size, child gender, and parental attitudes.

Another study examined the Metropolitan Readiness Test (MRT) scores of children in a school district in New York City. Comparisons between a class of students that had attended school for two years before the airing of the first season of Sesame Street and a class that had attended school during the first year of the broadcast showed that the latter group scored significantly better on the alphabet subtest, with no significant differences on the other subtests (Minton, 1975).

According to a third study that looked at television viewing of low-income children in the 2-5 age group, viewing informative programs aimed at a child audience (Sesame Street comprised 80% of all such programming in the study) between ages of 2 and 3 predicted high subsequent performance on standardized tests of reading, math, receptive vocabulary, and school readiness. Moreover, children who watched general-audience programming fared worse on those same measurements (Wright et al., 2001).

A minority of scholars expressed doubts about Sesame Street. Most of these criticisms were based on instinct and therefore subjective (Panos, 1981), although a few were grounded in research. In a 1975 book that revaluated earlier studies, Cook and others concluded that viewers had indeed made gains on achievement but these gains could not have been achieved without encouragement to watch. In addition, this revaluation showed that the achievement gap between advantaged and disadvantaged children had widened as a result of Sesame Street. However, the authors acknowledged that the amount of time spent watching was directly related to parent education and income (Cook et al., 1975). Therefore, it might not have been the content of the show, rather the fact that disadvantaged students watched the show less than the advantaged ones, that caused the achievement gap to widen. Moreover, narrowing the achievement gap was not and could not have been a goal of Sesame Street because of the ubiquitous nature of television programming (Who Wants to Live on Sesame Street, 1973).

Sesame Street was also criticized for emphasizing basic skills at the expense of skills that required more complex logical thought, reasoning, and knowledge of spatial and temporal concepts. This view can be seen in Panos's analysis of "Piaget Does Not Live on Sesame Street"—Kay Beck's evaluation of the ETS studies. Beck contended that unlike the Swiss philosopher Jean Piaget, who was well known for his studies of children and who stressed "operative (manipulative) knowledge," Sesame Street emphasized "figurative (memorization) knowledge" (Panos, 1981). While this is a fair criticism, Sesame Street was never intended to develop children's operative knowledge. From the other studies cited it is clear that the program did achieve most of its instructional goals.

Another study was conducted by H. A. Sprigle over a two-year period (described in Who Wants to Live on Sesame Street, 1973). The experimental group watched Sesame Street, and the control group was instead given classroom learning experiences in a game format with added emphasis on emotional and social development. On the Metropolitan Readiness Test, the experimental group scored lower. However, as Children's Television Workshop pointed out, Sesame Street was never meant to replace or be better than classroom curriculum. Moreover, many researchers questioned the validity of Sprigle's study. G. M. Ingersoll doubted that the control group was a true one in an experimental sense, since Sesame Street aired many times during the evenings, weekends, and summer in addition to its normal broadcast hours, making it possible for children in the control group to have watched the program. (Panos, 1981).

Based on a variety of independent evaluations, it is fair to say that Sesame Street had a significant educational impact on its viewers. It was a cost effective means of imparting preschool education at a time when most school-age children were receiving no early childhood education. The program did achieve most of its instructional goals and had a significant impact on its primary target population of disadvantaged students. However, it did not narrow the achievement gap, nor was it intended to do so.

PLATO: An Early Computer-Assisted Instructional System

Today, much of the attention of educational technology is focused on computer-assisted instruction (CAI) and its variations, including computer-based and computer-managed instruction. For example, the state of Maine has made a laptop available to all of its middle school students for educational use. Moreover, efforts are underway across the country to utilize the ever-growing capabilities of advanced computing for education. Computers are used for everything from elementary learning activities like drill and practice to complex simulations that approximate real-life situations and help students grasp concepts better than traditional means do.

The federal government's role in technologies for computer-assisted instruction in elementary and secondary education dates back more than half a century. One of the earliest federally supported efforts was PLATO, or Programmed Logic for Automatic Teaching Operations.

Background

PLATO is a computer-based educational system that was developed at the University of Illinois through the PLATO project, initiated in 1959. It was designed for use with conventional and multimedia learning aids (OTA, 1982). The impetus for computer-assisted instruction, and for PLATO in particular, was the increasing enrollment in educational institutions during this period and the corresponding exponential increase in educational costs (Van Meer, 2003). The PLATO project started out in the belief that the technology available at the time was not making a noticeable difference in education at any level, from elementary through college. Unlike many other CAI systems of its time, PLATO was one of the few with significant R&D in all aspects of its design, including hardware, software, teaching strategies, and lesson materials (Alpert & Bitzer, 1969).

PLATO was developed in two phases, each with distinct but related objectives. The first phase investigated the potential role of the computer in education, and the second sought to design an economical system that implemented teaching and learning goals that were laid out in the first phase (Alpert & Bitzer, 1969). The original system combined a novel, interactive graphics terminal with a touch-sensitive screen and a multi-terminal computer system; the system used an elaborate language (TUTOR) specifically designed for creating instructional programs. The many terminals were connected to a central computer via cables, long-distance telephone lines, or satellite. Individuals or groups of students had access to instructional materials ranging from drill and tutorials to presentations, dialogs, simulations, and games. By its third version, PLATO could provide not only drill and practice but also more advanced instruction. As microcomputers and discs became prevalent, PLATO was also used as a stand-alone application on a single computer (OTA, 1982).

PLATO I, II, and III were designed and built under phase one during the period from 1960-66, without regard to economic constraints. A big improvement in PLATO III was the addition of the TUTOR language, which allowed teachers to design their own courses and required no prior experience with or knowledge of computer programming (Van Meer, 2003). Plato IV was built in phase two and was operational in 1972. It was capable of providing instruction at a cost of 35 cents per student contact hour (Alpert & Bitzer, 1969).

Federal Involvement and Early Funding

As with Sesame Street and other educational technologies of the day, federal involvement for PLATO came in the form of funding. Early financial support for PLATO came from a combined Army, Navy, and Air Force grant through the Coordinated Science Laboratory at the University of Illinois. The National Science Foundation (NSF) provided full support for the development of

PLATO IV with the requirement to accommodate at least 300 PLATO terminals (Van Meer, 2003). This support lasted from 1968 to 1976 (Lyman, 1978). The U.S. Office of Education provided some funding as well (OTA, 1982). Under the NSF grant, the Computer-based Education Research Laboratory (CERL) was set up at the university to oversee the continuing work of PLATO. Minor sources of funding included the state of Illinois, the Ford Foundation, and the U. S. Department of Health, Education, and Welfare (Lyman, 1978).

Analysis

As noted above, PLATO was not designed exclusively for the pre-college audience, so many studies evaluate the effects of PLATO at various levels of education. For purposes of this paper, only those research undertakings that pertain to elementary and secondary education are analyzed. Most of these evaluations examined improvement in student achievement, as evidenced through test scores.

It should be kept in mind that only four years elapsed between the 1972 introduction of PLATO IV, the first version to be made available to elementary and secondary students, and the 1976 acquisition of PLATO by Control Data Corporation (CDC) (Van Meer, 2003). Consequently, the research studies chosen for this paper were limited to those that analyzed the effects of PLATO during this period when the federal government played a significant role.

Only one evaluation of PLATO was found that met these criteria, but it was a comprehensive one—the PLATO Elementary Demonstration Educational Outcome Evaluation done by ETS. This evaluation looked at the impact of a demonstration of PLATO conducted by CERL and funded by NSF. As part of this demonstration, approximately 100 terminals were placed in elementary classrooms in the Urbana-Champaign area for a three-year period. For the 1974-75 and 1975-76 evaluations, a PLATO reading curriculum was developed for 700 students in kindergarten to grade 2 and a PLATO math curriculum for 300 students in grades 4-6 to supplement classroom instruction (Swinton et al., 1978). About 43,000 hours of PLATO instruction were delivered over the course of the study in the elementary classrooms. Each student in the PLATO group had access to a terminal for 20-35 minutes each day. Data were also collected from about a dozen roughly comparable non-PLATO classes in each of the years (Dugdale & Kibbey, 1977). Participating teachers were self-selected for the study, so this was not a randomized experiment but a naturalistic one. However, the authors did account for this factor in drawing their conclusions.

The PLATO Elementary Mathematics Curriculum was a clear success in a supplementary role. The evaluation found significant gains in achievement at all grades on the Comprehensive Test of Basic Skills, a standardized test, and on a specially constructed test of fractions. Additionally, grades 5 and 6 showed similar improvements on a test of graphs and linear equations, and students in grade 4 showed gains in whole number concepts. Another important outcome was the positive results of tests that measured concepts and operations beyond mere manipulation of symbols, which suggested that PLATO is capable of *teaching* and not just drill and practice of concepts already covered in the classroom (Swinton et al., 1978).

The PLATO Elementary Reading Curriculum, however, had a negative impact on 1st-grade reading achievement and kindergarten reading readiness achievement. In the evaluators' opinion, the slow-moving reading curriculum, which unlike the mathematics curriculum remained on lessons long after concepts were learned, did not focus strongly on meaning or understanding. Moreover, the evaluators pointed to problems with hardware, particularly the audio device, and the immaturity of the target population (Swinton et al., 1978). The problems with hardware are particularly important given the greater significance of audiovisual peripherals in reading and listening than in mathematics.

In addition to the achievement gains, evaluators noted that PLATO had a positive impact on students' attitudes to learning math. For example, students often sought extra math work sessions on PLATO beyond what was required (Dugdale & Kibbey, 1977). However, PLATO was found to have little impact on attitudes toward reading. Teachers generally appreciated the individualization provided by the system and considered PLATO effective in providing reinforcement and practice. In spite of their high regard for the system, teachers often did not take advantage of opportunities to review student feedback provided by the computer. Moreover, PLATO was often used as an isolated source of instruction, and few efforts were made to relate PLATO to classroom curriculum, a shortcoming that prevented integrated learning (Swinton et al., 1978).

As seen in this evaluation, PLATO's success was mixed; it was shown to be educationally effective in math instruction but not in reading. It also had benefits that were not quantifiable, such as increased motivation and greater opportunities for individualized instruction. Additionally, while the ETS evaluation was substantial, there was a dearth of additional studies to back up its claims. Even though this lack of research might seem to minimize the results, a look through another lens offers a different perspective. As described earlier, one reason for the lack of additional studies was the short time span of government support for PLATO. However, CDC acquired the rights to PLATO after only a brief period because of its commercial viability. While this fact does not add to the claims of educational effectiveness of PLATO, it could be argued that adoption by a private company is a greater testament to its success. Moreover, a number of studies since 1976 (Foshay, 2002) have shown the educational benefits of subsequent versions of PLATO. If not for the early R&D support by NSF and other government agencies, this would not have been possible.

An important failure to note is that PLATO IV, designed to make education more affordable, did not do so for the elementary and secondary levels of education. By the fall of 1976 (the year CDC acquired the system), only nine elementary schools and six high schools had PLATO (Lyman, 1978). Therefore, the PLATO project only partly satisfied its original objectives.

CAI at the Institute for Mathematical Studies in Social Sciences

Another early computer-assisted instruction initiative, the Computer Curriculum Corporation (CCC), was described by OTA (1982) as a landmark R&D effort to disseminate educational technology. But in fact, CCC was a marketing outreach effort of a pioneering, federally supported CAI research project that took place many years earlier at the Institute for Mathematical Studies in Social Sciences at Stanford University.

Background

The research and development of CAI started at the Institute in January 1963 (IMSSS, 1968). The motivation behind CAI was a desire to study complex learning, while having complete control over the material presented to students. Moreover, computers permitted interactive learning—something that could not be achieved through other mediums—in reading, math, and other key areas of elementary education (Rothenberg & Morgan, 1975).

The CAI system consisted of a central computer and a number of student workstations connected to it. Each workstation had two display devices—a touch screen that displayed microfilm material (this screen was later discontinued) and a cathode-ray tube, or scope, that was analogous to today's monitors and was capable of displaying 120 prearranged characters. A typewriter (keyboard) was attached to the scope that enabled the student to send information to the computer. The student workstation also had an audio system that played prerecorded messages stored on magnetic tapes (IMSSS, 1968). A significant technological factor in the development of CAI was the perfection of time-sharing—a state-of-the-art technique at the time—that allowed multiple users to be online at the same time and receive feedback from the main computer (Rothenberg & Morgan, 1975).

The first instructional program developed at the Institute was in elementary mathematical logic. It was demonstrated in December 1963, and consisted of two lessons that included 23 problems. By the end of 1964, the Institute made this program and an arithmetic program available to a number of 5th- and 6th-graders and kindergarteners, respectively. Over the next few years, courses were developed in algebra, symbolic logic, and reading for students at various levels. This period also saw the first use of off-campus student terminals that were connected to the main computer via telephone lines (IMSSS, 1968).

Three distinct types of CAI were developed over time at the Institute. The first was Tutorial CAI, a mode of instruction in which the computer taught most, if not, all of a given subject through lessons with simple and direct explanations of concepts. The lessons were followed by practice problems.

The second type, Block Drill-and-Practice CAI, left the presentation of new material to the classroom teacher and supplemented that instruction with drills of appropriate materials. Each drill and practice program was organized into blocks corresponding to the order of concepts in the textbook, *Sets and Numbers*. A block had five levels of competency. Students moved up or down based on their skill level after starting in the middle. To advance to the next block, a student had to master level 5 concepts.

The third type, Strands Drill-and-Practice,[3] was a modification of the Block type, but the drill and practice remained. The Strands type of CAI was better aligned with core material taught at a

[3] A strand is a series of problems of the same type—subtraction, fractions, etc.—arranged sequentially according to their relative difficulty (Suppes & Fletcher, 1974)

typical school than the Block type, which was tied to one book. However, the order of presentation was not tied to concepts covered in the classroom. The many strands were simply composed of material covered in grades 1 through 7, which allowed students to progress to higher levels. Additionally, Strands CAI did not store practice problems created manually but generated them on its own. This eliminated the possibility of students sharing answers. (Rothenberg & Morgan, 1975).

Federal Involvement and Funding

The initial funding for CAI was $1 million from the Carnegie Corporation. After the initial stage, 95% of the funding for R&D came from the National Science Foundation, a total of $15 million between 1964 and the early 1970s. Also, in the summer of 1964 the Office of Education granted a contract to establish a computer-based laboratory at a public elementary school. This lab was set up at Brentwood Elementary School in Palo Alto, California. In isolated cases, school districts used funds under Titles I and III of the Elementary and Secondary Education Act (ESEA) to implement the CAI technology in their schools (Rothenberg & Morgan, 1975).

Analysis

A number of studies have evaluated the efficacy of Computer-Assisted Instruction. Most of these were conducted by IMSSS. The evaluations chosen for analysis in this section cover a range of student demographics.

One three-year study sponsored by the U.S. Office of Education analyzed CAI in mathematics and language arts for hearing-impaired students. CAI was delivered to more than 1,000 students in the first year and more than 2,000 in the subsequent two years in 15 schools for the deaf. Students participating in the study were chosen from the 2,000-student group, were located in various parts of the country, and were part of the IMSSS national network. The mathematics curriculum provided supplementary curriculum and drills in deficient areas tailored to individual students' needs. Of the 2,000 students participating in the latter two years, 385 students were chosen and divided into five groups of 77. These groups received 10, 30, 70, 100, and 130 sessions of CAI, each lasting 6-10 minutes. The language arts curriculum was specifically tailored to the needs of the deaf students and stressed structure, with particular emphasis on the roles of syntax and inflection on word meanings. The curriculum was divided into 218 areas of 20-30 exercises. As in the case of mathematics, a subset of 235 students was further divided into five subgroups and received 20, 45, 70, 95, and 120 sessions of CAI (Suppes & Fletcher, 1974).

The educational effectiveness of the math CAI was evaluated by examining the post-test gains of the 385 students on arithmetic computation grade placement, as measured by a modified, online version of the Stanford Achievement Test (SAT). The students using mathematics strands CAI were found to have made significant gains—roughly a 0.1 increase in grade placement for every 12 sessions. The gains were comparable to those expected of students with normal hearing. The language arts CAI was evaluated through student performance on a pencil-and-paper test developed by the project. The results were less straightforward than in math. CAI produced significant gains only for those students who had a high ratio of lessons completed to sessions taken. For those students who had a low ratio, the CAI was of much less value (Suppes & Fletcher, 1974).

A second study by Jamison and colleagues looked at the effectiveness of CAI in initial reading (kindergarten through grade 3). The study subjects were chosen from four schools within the same district in an economically depressed area (Jamison et al., 1971).

Reading instruction was divided into seven strands—readiness, letter, word, spelling pattern, phonics, comprehension categories, and comprehension sentences. Twenty-two pairs of boys and twenty-two pairs of girls were matched according to their performances on the Metropolitan Readiness Test. Members of a pair were drawn from similar classrooms, were taught by individuals of comparable teaching ability, and had scored within two points of each other on the MRT. The experimental members of the pairs received 8-10 minutes of CAI every day for roughly five and a half months, while there was no change to the schooling of the control members. Three post-tests were offered: the Stanford Achievement Test, California Cooperative Primary Reading Test (COOP),[4] and a test developed at Stanford tailored to the needs of the CAI curriculum. All the comparisons showed notable gains for the CAI group except for the COOP among girls. Moreover, there were improvements in more general reading skills that were only remotely related to the phonics emphasis of the CAI curriculum. The study also suggested that CAI is more effective for boys than girls (Fletcher & Atkinson, 1972).

The same study also looked at the effectiveness of CAI in arithmetic and computer programming in two different groups of students—1,000 upper-middle-class students in California and 600 poor and “culturally deprived” students in Mississippi. In Mississippi, students from grades 1-6 in twelve different schools[5] were part of the study. In California, seven schools[6] were used, and the students were from the same grade levels as in Mississippi. In Mississippi, the performance of the CAI students showed significant improvement over the non-CAI group in all but one of the six grades, as measured by pre- and post-test scores on the SAT computation subscale. A similar result was found on the SAT concepts subscale for grades 3 and 6 and the SAT application subscale for grade 6. However, the non-CAI group outperformed their CAI peers on the SAT concepts subscale in grade 4. In California, as in Mississippi, CAI students showed significant gains on the SAT computation measurement, although the gains were limited to grades 2, 3, and 5. The CAI group also performed better on the concepts and application subscales in grades 3 and 6, respectively. A comparison of data from the two states revealed that the CAI program had more significant effects on the students from Mississippi than from California. Moreover, while the CAI groups had similar changes, the Mississippi non-CAI group’s changes were very small compared to the California group’s changes. These

[4]Not all tests of the SAT or the COOP were used. The subtests used were word reading, paragraph meaning, vocabulary, and word study (on the SAT), and Form 12A (Grade 1, reading) on COOP.

[5]Eight schools had both CAI and non-CAI students, three had only CAI students, and one had only non-CAI students. In the CAI group, 1-10 classes were tested at each grade level, and 2-6 classes were tested for the non-CAI group.

[6]Two schools had both CAI and non-CAI students, two had only CAI students, and three had only non-CAI students. In the CAI group, 5-9 classes were tested at each grade level, and 6-14 classes were tested in the non-CAI group.

observations suggest that CAI may be more effective for low-achieving students than for others (Jamison et al., 1971).

The computer programming curriculum was evaluated using the SAT computation and application subtests, since there was no standardized achievement test in computer programming at the time. For that reason, a large part of the gains for the CAI group cannot accurately be attributed to CAI, since the gains might have been due to improved performance in mathematics.

From these evaluations, it is reasonable to conclude that the CAI initiative begun at IMSSS was mostly successful in achieving its instructional goals wherever it was implemented. Not only was it able to provide drill and practice, in some instances it even allowed for supplementary instruction. It was successful in delivering individualized learning at the pace and difficulty level of the user. Although improving equity in instruction was not one of the initiative's goals, at least one of the studies seemed to suggest that CAI can be effective for students from low-income families.

Like PLATO, however, CAI failed to take root on a large scale in U.S. public schools. The primary reason for this was cost. The R&D aspect of CAI was often funded by grants through federal agencies that explicitly specified what the funds should be used for. But, as alluded to earlier, the implementation part was often funded by sources like ESEA Titles I and III, which provided discretionary funds. School districts were often reluctant to use their own precious dollars on CAI, which, even after considerable reductions in cost over the years, cost $0.44 per student contact hour. In comparison, traditional instruction was estimated to cost $0.27 per student contact hour (Rothenberg & Morgan, 1975).

Star Schools: Distance Learning

By the late 1980s, educational researchers and practitioners had begun to see the potential of distance learning—transmitting instruction to students in disparate locations. Tapping the potential of distance learning required more than the televisions and computers that formed the basis of earlier technology-based instructional systems; it required a solid technology infrastructure that included two-way telecommunications technologies. Therefore, the goals of building infrastructure and promoting distance learning have often been intertwined in the educational technology initiatives of the past 30 years.

One of the earliest and most expansive federal efforts to support distance learning was the Star Schools program, which sought to use technology to improve instruction in mathematics, science, foreign languages, and other subjects. Star Schools was implemented by the federal government through the Star Schools Program Assistance Act of 1988 (20 U.S.C. 4081) and was created to serve underserved populations, including disadvantaged, non-reading, and limited English proficient students, as well as individuals with disabilities.

Background

Under the Star Schools program, competitive grants are made to eligible telecommunications partnerships[7] to enable them to secure and maintain audiovisual facilities and equipment. The grants are used for educational and instructional programs that employ this infrastructure and for technical assistance needed to operate these educational programs. Initially, grants were limited to two years and projects were barred from repeat funding, but the latter provision was eliminated with the third grant cycle. The services supported include securing programming in different curriculum areas, providing teacher training and staff development to improve instruction, offering technology-based tutoring for students, and maintaining testing services for courses (U.S. Department of Education, 2006; Tushnet et al., 1994).

Predominantly, Star Schools projects utilized satellite-based instruction with audio return. This technology was critical in reaching rural areas in the pre-Internet age. Some projects, however, used fax machines and telephones to exchange questions, assignments, and feedback. A few projects used computer networks, modems, e-mails, laserdisc players, and VCRs (Tushnet et al., 1994).

Through the years, Star Schools has supported many different types of projects, including general projects, dissemination projects, statewide projects, and evaluation projects, among others. A general project provided distance learning programming that addressed the National Education Goals in key areas of instruction. A dissemination project communicated information about Star Schools to educators, parents, and community leaders. Such projects also provided consultation services to schools and school districts that wished to participate in the program. Statewide projects, as the name suggests, pertained to programs for an entire state, such as designing telecommunication networks. An evaluation project would have been set up to assess the impact of a particular program (Sanchez & Lane, 1996).

Funding

In the first year of Star Schools' existence, \$33.5 million was appropriated over a three-year period; \$19 million was spent in 1988 alone on four projects.[8] Under the original authorizing legislation, at least 50% of the appropriations had to be made available to schools districts eligible for Chapter 1[9] funding. In addition, 25% of the funds had to be spent on instructional programming. At least 25% of the total budget for each program had to come from non-federal

[7]An eligible partnership had to include three or more agencies, one of which had to be a state or a local education agency serving a significant number of students under Title I of ESEA, or an elementary or secondary school administered through the Bureau of Indian Affairs and serving Indian children. The other members of the partnership could be an adult or family education program, a higher education institution or a state agency, a teacher training institute that received federal funding or state approval, a private or public entity with expertise in telecommunications networks, or a public or private elementary or secondary school. The other type of eligible partnerships consisted of public agencies or corporations established to create or operate telecommunications networks to enhance educational opportunities provided by education institutions that served Title I children.

[8]These were the Satellite Educational Resources Consortium (SERC), TI-IN United Star Network (TI-IN USN), the Midlands Consortium, and Technical Education Research Centers (TERC).

[9]Districts eligible for funding under Chapter 1 (the name of the ESEA Title I program in the mid-1980s) were those that enrolled at least 10 students from low-income families.

sources. In years following passage of the legislation, federal funding continued with small variations; $13 million was spent in 1992 and approximately $19 million in 1993. During the past three years, funding has decreased. Although more than $20 million was appropriated in 2004 and 2005, funding was reduced to $14 million in 2006 and $11 million in 2007. Star Schools received no appropriations in fiscal year 2008 (U.S. Department of Education, 2008; Tushnet et al., 1994; OTA, 1989).

Analysis

The most comprehensive evaluation of the Star Schools program was done by Abt Associates and the Southwest Regional Laboratory (SWRL), under the sponsorship of the U.S. Department of Education (Tushnet et al., 1994). This study looked at a variety of factors, including the different projects[10] undertaken by grantees, the characteristics of student participants, the educational effectiveness of the programs, and teacher and staff participation, development, and assistance.

In terms of student outcomes, only a limited amount of data was collected by the administrators of the projects because this type of data was not required by the funders. Moreover, the short (two year) duration of most projects made it difficult to amass sufficient data. Often a project did not get going until the second year, and the staff felt such a schedule permitted too little time to conduct student outcome analysis. However, a few projects did provide valuable outcome data.

One Star Schools project reported that 88% of distance learners received a grade of C or better in the virtual course (42% received A's); however, there were no comparison data from traditional classrooms. In the projects that did provide comparison data, the results were mixed. In one case, students in the distance learning course scored lower in all disciplines. A second project found that distance learners performed better, but the test was compromised, since items were changed from pre-test to post-test, and 40% of the distance learners received additional time to finish the test. A third test did show a 45% gain for distance learners without caveats. Another project looked at participating Chapter 1 students (a former name for Title I of ESEA) and found gains among 16 of 24 middle school students (Tushnet et al., 1994).

Although student outcome data were minimal, teacher responses collected through formal interviews and surveys were supportive of distance learning. In one project, teachers reported that academically disadvantaged students were better off in a distance learning environment than in a traditional classroom. In another project, teacher responses indicated that minority and learning disabled students had higher attendance on days when distance learning was used. An overriding observation from teachers was the rise in student motivation during broadcast instruction. Increased student interest was also evident in the participation of close to 100,000 learners in Star Schools programs. It has been estimated that 57% of students served through Star Schools were minority children, 40% were educationally disadvantaged, and 77% were from Chapter 1 eligible schools (Tushnet et al., 1994). By 1996, over a million students were participating in Star Schools programs nationwide (Sanchez & Lane, 1996).

[10]Projects evaluated included CETC, MCET, Midlands, SERC, STEP, TEAMS, TERC, and TI-IN.

Various Star Schools projects were also found to have a significant impact on teachers. In one project, an overwhelming majority of teachers (86%) switched to different instructional materials due to their participation. Teachers reported increases in using multiple technologies, introducing innovative ways of teaching science, and giving greater emphasis to small group activities. While the self-reported data showed changes, the staffing patterns at schools remained unchanged (Tushnet et al., 1994).

An evaluation of one Star Schools project, the Midlands Consortium, was conducted for the U.S. Department of Education under the aegis of the Midlands Consortium Research and Evaluation Center. The consortium was a partnership among five universities—Alabama-Birmingham, Kansas, Kansas State, Oklahoma, and Mississippi—and the Missouri School Boards Association, and the project it sponsored spanned five states (Midlands Consortium, 1991; OTA, 1989). This evaluation’s finding supports the observations in the Abt Associates/SWRL study. It also provides some additional insights.

The Midlands Consortium played an instrumental role in providing the necessary equipment and services to enable 133 disadvantaged and isolated school districts in Kansas, Oklahoma, and Mississippi to participate in satellite instruction. The Consortium study found that a substantial number of minority students participated in distance learning courses in calculus and physics when compared with course taking in these subjects in conventional classrooms. The study also found no significant difference in performance between satellite and conventional students as measured by standardized subject matter tests. According to the study, the Midlands Consortium had succeeded in meeting the needs of at-risk[11] students. At-risk students were also found to perform better on standardized tests in satellite classrooms than in conventional classrooms (Midlands Consortium, 1991).

The available data seem to suggest that Star Schools was more or less successful in achieving its goals. It expanded learning opportunities for thousands of students in disadvantaged areas, including rural school districts that lacked the infrastructure and other resources to provide conventional classroom instruction. However, the program had a mixed impact on educational effectiveness as measured through test scores and grades. Moreover, assessing this effectiveness was made harder by the fact that there were often no control groups, since distance education was often meant to provide instruction that was otherwise unavailable. There was some indication that projects also provided increased motivation for at-risk and disadvantaged children. There were noticeable differences in teacher behavior in classrooms and attitudes toward teaching. The partnerships, which created the projects, enabled division of labor and allowed individuals and groups with expertise in areas as diverse as pedagogy, technology, and curriculum to come together to achieve the results. The two-year funding structure, however, seemed to cause disruptions at times in the smooth operation of schools.

E-Rate: Expanded Access to Telecommunications Technologies

[11] At-risk was defined as having low prior achievement, an absence of motivation or interest in schoolwork, and a tendency to think simplistically and invest little time or effort in schoolwork.

Like Star Schools, the E-Rate (short for educational rate) initiative combines features of a distance learning program and an infrastructure building effort. E-Rate is the common name for the Universal Service Fund for Schools and Libraries. It was established through the Snowe-Rockefeller amendment to the Telecommunications Act of 1996. The E-Rate program provides discounts to libraries and schools to help them acquire or maintain telecommunications services. The program is administered by the Schools and Libraries Division (SLD) of the Universal Service Administrative Company, a private, nonprofit organization. Virtually all public and private K-12 schools[12] are eligible to participate (Benton Foundation, 2000; Revenaugh, 1999).

School districts are responsible for paying suppliers the non-discounted price, and the SLD is charged with reimbursing the buyer. Discounts for schools can range anywhere from 20 to 90% depending on the percentage of students who are eligible for free and reduced-price lunch—the higher the percentage, the higher the discount. The discounts can apply to services in three broad categories: telecommunications services, including voice and high-speed data lines; Internet access; and internal connections, which include wiring and equipment, such as servers, hubs, and cabling, inside a school building. No discount can be obtained for computers, curriculum software, or teacher training (Revenaugh, 1999).

Policymakers cited three main justifications for E-Rate. The first was economic; namely, that making technologies available to students would prepare them for an economy where a majority of jobs demand information technology (IT) know-how. The second was educational, that students would have access to a greater range of resources and services. Third, policymakers reasoned that building IT infrastructure in underserved communities, such as rural areas and inner cities, would help close the digital divide (Benton Foundation, 2000).

Funding

The maximum funding for E-Rate under the statute is $2.25 billion. The funding comes from the Universal Service Fund, which is financed by fees paid by telecommunications companies. In the first cycle, $1.66 billion was provided over an 18-month period in 1998-99. Starting in the second year, funding was provided for 12-month intervals. In 1999-00, the maximum funding allowed by the legislation was disbursed, and in 2000-01, $2.1 billion was provided. It should be noted that the requests for funding from schools and libraries totaled $4.72 billion in 2000-01 (Goolsbee & Guryan, 2006; Puma et al., 2000).

Analysis

One of the first studies to evaluate the E-Rate was conducted by Education Development Center, Inc. and the Center for Children and Technology under the sponsorship of the Benton Foundation. The study was conducted in four large urban districts—Chicago, Cleveland, Detroit, and Milwaukee—in the fall of 1999. These districts together served approximately 800,000 mostly poor students. This study found that there was accelerated deployment of networks and Internet services in school districts as a result of E-Rate. The savings that resulted from E-Rate discounts were combined with other district and statewide resources to ramp up infrastructure in

[12] Only for-profit schools and those with endowments of more than $50 million are prevented from participating.

areas not covered by E-rate. However, in some cases, E-Rate's lack of coverage of electrical upgrades and computer hardware slowed down the deployment of information technology.

The study also concluded that professional development needs were increasing and that additional resources for professional development were critical to the success of any information technology program. The E-Rate program was found to be a positive force for collaboration between various departments, especially between technology and instructional administrators. However, the funding structure of the program created rifts between districts and vendors. The requirement to pay the non-discounted price, the delays in receiving reimbursements, and the shortage of inventories and labor contributed to the frictions (Benton Foundation, 2000).

A formative evaluation of the E-Rate program, conducted by the Urban Institute for the U.S. Department of Education, set out to answer two questions: 1) to what extent does E-Rate equalize access to educational technology, and 2) what is the role of E-Rate in the broader context of student learning? (U.S. Department of Education, 2003). The evaluation was based on an analysis of E-Rate administrative records for the first two years of the program.

The Urban Institute evaluation determined that public schools benefited the most from the program. Though E-Rate was designed for private and public schools, as well as libraries, most of the funds (84%) went to public schools. E-Rate also had the most impact in poor communities. It was found that per student funding increased with poverty, with the most disadvantaged districts receiving almost 10 times as much funding per student as the least disadvantaged ones. In the first year of the program, the application rates for the poorest districts were lower than those of most other districts, but this started to change in the second year. Large school districts, irrespective of location or economic status, were found to have higher application rates as well as higher average funding per student. Urban areas, which have higher concentrations of poor students, and rural areas were found to receive higher per student funding. According to the study, most of the program funds were used for internal connections (58%). Per student funding for internal connections was especially high in high-poverty districts, reflecting the dilapidated infrastructure in their schools (Puma et al., 2000).

A third study looked at E-Rate's impact in rural areas and was conducted by the Center for the Study of Rural America at the Federal Reserve Bank of Kansas City. The study found that 23% and 32% of funding in the first two cycles went to rural institutions. Approximately three-fourths of those sums were used for internal infrastructure development. In some states, per capita funding in rural areas was lower than per capita funding for the entire state. However, in a majority of the states the rural funding was higher using this measure. The study determined that E-Rate was successful in bringing much needed technology infrastructure to geographically isolated regions (Staihr & Sheaff, 2001).

While the aforementioned studies looked at the penetration of E-Rate funds and the infrastructure that resulted, they do not give any perspectives on whether the subsidies had any effects on student achievement. A study conducted in California by Goolsbee and Guryan sheds some light on this measure. The study looked at whether students in schools with high subsidy rates improved their achievement more than students in schools with low subsidy rates.

Achievement was measured by performance on the Stanford Achievement Test[13] in six subjects: math, reading, science, language, spelling, and social studies. The study focused on the impact of subsidies in the year after the program was first implemented to allow enough time for technologies to be set up. For all six subjects, it was found that the subsidies had a small but statistically insignificant effect on student achievement. When looked at again after two years of program rollout, it was found that the effects had lessened for the high subsidy group (Goolsbee & Guryan, 2006). However, the study mostly agreed with the earlier findings that pertain to access to technology.

As evidenced in these evaluations, E-Rate succeeded in connecting America's public schools to the information superhighway. It was instrumental in providing the necessary funds to equip the poorest districts and thereby closed the digital divide to a certain extent. The scaled incentive system of the program was critical to achieving this goal. However, these studies give cause for concern about the educational effectiveness of the program. Students in schools that received the most subsidies did not perform better on achievement tests. As Goolsbee & Guryan pointed out, this could be because traditional standardized tests do not measure the skills learned through technology-based instruction. Or, it could be because technology, once acquired, is catching dust and not utilized to its fullest potential. A 1999 Department of Education survey, cited by Goolsbee & Guryan, offers support for this alternate explanation; the 1999 study found that only one-third of teachers felt prepared to use computers and Internet in the classroom.

This lack of preparation among teachers raises another important issue regarding professional development related to the program. Although, E-Rate gave generous subsidies to school districts, no funds were allotted for staff and teacher training. This meant local authorities, often strapped for cash, had to scramble to provide the necessary funds. If one considers the research that suggests that schools must spend close to 30% of their technology budget on professional development (Carvin, 2000), it can be argued that E-Rate left out a very important aspect of educational technology.

Findings

Several findings about the federal role in educational technology emerged from this review of research on five major programs.

- ***The five major federal initiatives in educational technology of the past half-century fulfilled their goals.*** Sesame Street, PLATO, CAI research at Stanford, Star Schools, and E-Rate achieved most of their objectives. All but E-Rate were found to be educationally effective. E-Rate and Star Schools brought technology infrastructure to underserved areas, and CAI was found to reduce the achievement gap to a certain extent. However, there were a few failures. CAI failed to become the affordable learning medium it had promised. Lack of professional development meant infrastructure improvements were not

[13] Public school students in California were required to take the SAT starting in 1997, the year before E-Rate was implemented.

utilized to their fullest potential. Overall, educational technology was also found to motivate students and strike their curiosity more than traditional instruction.

- ***The most successful programs had federal support at every step of development and implementation.*** While all of the programs analyzed in this paper were successful by some measure or another, the ones that succeeded the most had federal support in virtually all areas. Sesame Street, arguably the most successful, had full federal funding in design and development. Even though there was no funding for equipment at the consumer level, the ubiquity of televisions took care of that aspect. In contrast, PLATO and CAI at Stanford, although they were found to have substantial educational effects, failed to get established in schools because of lack of funds for implementation.

- ***The use of explicit language in legislation to dedicate funds to particular technologies may do more harm than good, given the rapid evolution of technology and languid pace of legislation.*** In the case of E-Rate, the language of the initial legislation limited schools to hardwiring buildings to improve telecommunications infrastructure. This meant that schools were stuck with installing obsolete technological infrastructure until policymakers updated the statute to allow wireless networks and similar technology. By comparison, the funding parameters for Sesame Street and CAI gave researchers and collaborators freedom to experiment with different ideas and designs before settling on a final product. During the preparation year, Sesame Street creators were able to pilot different contents and formats to sample audiences. CAI researchers were able to obtain central computers and terminals that were at the frontier of technology innovation.

- ***A proactive federal role is necessary to provide educational technology to underserved groups and regions of the country.*** The experience of Sesame Street, Star Schools, and E-Rate shows that without federal leadership, educational technology as it exists today would never have reached disadvantaged students and communities to the extent it has. These projects specifically targeted areas ignored by the private sector due to increased risks and high startup costs. Educational television, which encompasses Sesame Street, was and is not seen as a profit-making field. Also, the chances for a return on investment in providing infrastructure in rural areas and inner-city neighborhoods are incredibly slim. Moreover, even if the private sector were to produce the equipment and services, school districts in the aforementioned areas often lacked the resources to secure them.

- ***Despite the successes of the programs, educational technology has several limitations.*** Technology is not a panacea by any means. In each of the programs analyzed in this report, technology was used in addition to the traditional curriculum. For example, CAI, though found to be educationally effective, was only successful in a supplementary role. Additionally, its curriculum was largely limited to mathematics and reading or language arts. It is not clear whether CAI can benefit students in other subjects. In the case of E-Rate, although it succeeded in providing infrastructure and connectivity, it has yet to make a difference in student achievement despite the large investment. Moreover, school districts often went ahead with procuring equipment and services because there was funding available for them but they did not always have a plan to use the acquired technologies in conjunction with the regular curriculum. Therefore, it is unwise to completely rely on technology to remedy public education's woes.

Recommendations

In light of these findings, federal policymakers should consider the following recommendations to ensure that the federal government will have a significant impact on educational technology in the future:

- ***Federal policymakers should increase the use of grants to foster innovation in educational technology.*** Instead of providing funds to implement specific technologies in schools through mechanisms such as the E-Rate legislation, policymakers should make more funds available to agencies such as the National Science Foundation and the U.S. Department of Education to provide grants to innovators to spur new developments in educational technology. Funds that are dedicated to a particular cause will limit stakeholders' technology options. Grant funding will offer for more flexibility and allow researchers to incorporate the latest advancements into ongoing projects. This is especially relevant in the present climate, where students are often ahead of policymakers and educational technology developers in using the latest applications (such as social networking).

- ***The federal government should provide funding for landmark educational technology programs at every step of the process.*** Once a technology is developed, the federal government should ensure that states and school districts have enough resources to implement and utilize the technology to its fullest potential. Funding must not stop with the acquisition of new technology; it should extend to professional development, maintenance and upgrades, and incorporation of educational technology into the broader curriculum. Otherwise new technologies will become relics in the classroom or will not be adopted at all on a large scale, as in the case of CAI.

- ***The federal government should continue to act as a balancing force and provide advanced technologies to underserved students and communities.*** The development and introduction of advanced educational technologies are prohibitively expensive, especially in the early stages. Moreover, the private sector has no incentives to provide these technologies to rural and lower-income districts at affordable prices. The federal government should provide the necessary supplementary resources to those areas to implement cutting-edge technologies in their schools. Without such federal intervention, the achievement gap and digital divide will widen even more, given the rapidly evolving technology environment.

Looking Ahead

Educational technology has received a remarkable makeover in the past fifty years. The ubiquity of personal computers and the emergence of the Internet have truly revolutionized the field in ways unimaginable a few decades ago. Online schools, podcasts, and computer-based testing have become the norm at many institutions. The Massachusetts Institute of Technology, for example, has made available most of its curriculum free of charge online through the OpenCourseware project. Innovative learning environments, which unlike traditional methods engage children in an increasingly distracting digital world, are being piloted at selected schools. Some of these technologies may even provide individualized learning. Research continues to takes place at leading universities on cutting-edge technologies such as handheld learning devices.

Technology would also serve well in areas of the education system that do not directly pertain to learning. Much focus is on accountability and demands for school improvement in the era after passage of the No Child Left Behind Act. Information technology would be of great assistance in organizing the large amounts of data associated with demonstrating adequate yearly progress and meeting other school and student performance metrics. Better use of technology would also make many administrative tasks, such as monitoring of student progress, more efficient. Such improvements would let teachers and other school officials do that which is most important—cater to the needs of individual students.

These characteristics of educational technology point to a future where educational technology is a cornerstone of public education in the United States. However, if the benefits of technology are to be fully realized, *all* schools must have the necessary infrastructure to support the innovations. The American Recovery and Reinvestment Act, widely known as the 2009 economic stimulus bill, takes a significant step in this direction by allocating $650 million to educational technology, which includes funds for broadband access and other network services (Moses, 2009). Funding has also been designated under the same legislation for 21st century classrooms and other new technologies (EdNews.org, 2009). While such allocations are encouraging, more can be done to ensure that this newfound pool of money is spent wisely.

First, the magnitude of funds involved provides an opportunity to initiate many landmark technologies. Programs such as Sesame Street, which received federal funding at every step of the research and development process, can once again become prevalent in the educational sphere.

Second, with every allocation made to a particular technology, enough funding should be set aside for implementation and evaluation. This would ensure that not only are new technologies developed, but also that their use becomes widespread. Moreover, lessons learned from the evaluation stage would allow for critical reflections on the technology as well as provide valuable insights for future research.

These steps would be a good start to ensure that the stimulus funds in educational technology yield significant results. However, federal efforts in educational technology should not stop there. To ensure steady progress in educational technology, the federal government should put the pedal to the metal and continue to take an active leadership in this area in the years and decades ahead.

References

Alpert, D., & Bitzer, D. L. (1969). *Advances in computer-based education: A progress report on the PLATO program.* Urbana-Champaign, IL: University of Illinois.

Ball, S., & Bogatz, G. A. (1970). *A summary of the major findings in "The first year of Sesame Street: An evaluation."* Princeton, NJ: Educational Testing Service.

Ball, S., & Bogatz, G. A. (1971). *A summary of the major findings in "The second year of Sesame Street: A continuing evaluation."* Princeton, NJ: Educational Testing Service.

Benton Foundation. (2000, Feb). *The E-Rate in America: A tale of four cities*. Washington, DC: Author.

Carvin, A. (2000). Rating the E-Rate: Making sure the investment pays off. *Multimedia Schools, 7*(2).

Cook, T. D., Appleton, H., Conner, R. F., Schaffer, A., Tamkin, G., et al. (1975). *"Sesame Street" revisited*. New York, NY: Russell Sage Foundation.

Cooney, J.G. (1970). *The first year of Sesame Street: A history and overview. Final report, volume I.* New York, NY: Children's Television Workshop.

Dede, C. (n.d.). Six challenges for educational technology. Retrieved on June 30, 2008, from http://www.virtual.gmu.edu/pdf/ASCD.pdf

Dugdale, S., & Kibbey, D. (1977). *Elementary mathematics with PLATO*. Urbana, IL: Computer-based Education Research Laboratory, University of Illinois.

Fletcher, J. D., & Atkinson, R.C. (1972). Evaluation of the Stanford CAI program in initial reading. *Journal of Educational Psychology, 63*(6), 597-602.

EdNews.org. (2009, Feb. 19). Stimulus package sees education technology's importance to U.S. competitiveness. *EdNews.org*. Retrieved Feb. 28, 2009, from http://ednews.org/articles/34125/1/Stimulus-Package-Sees-Education-Technologys-Importance-to-US-Competitiveness/Page1.html

Foshay, R. (2002). *An overview of the research base of PLATO. Technical paper*. Bloomington, MN: PLATO Learning, Inc.

Goolsbee, A., & Guryan, J. (2006). World wide wonder? Measuring the (non-)impact of Internet subsidies to public schools. *Education Next*, *6*(1), 60-65.

Institute for Mathematical Studies in the Social Sciences (IMSSS), Stanford University. (1968). *Brief history of computer-assisted instruction at the Institute for Mathematical Studies in the Social Sciences.* Stanford, CA: Author.

Jamison, D., Fletcher, J. D., Suppes, P., & Atkinson, R. (1971). *Cost and performance of computer-assisted instruction for education of disadvantaged children*. Stanford, CA: Stanford University.

Lyman, E.R. (1978). *PLATO highlights*. Urbana, IL: Computer-Based Education Research Laboratory, University of Illinois.

Midlands Consortium. (1991). *The Midlands Consortium Star Schools project: Final report* Washington, DC: Author.

Minton, J. H. (1975). The impact of Sesame Street on readiness. *Sociology of Education*, *48*(2), 141-151.

Moses, A. R. (2009, Feb. 20). Stimulus package to quickly impact education technology. *Edutopia*. Retrieved Feb. 28, 2009, from http://www.edutopia.org/economic-stimulus-education-school-technology

Office of Technology Assessment, U. S. Congress. (1982). *Information technology and its impact on American education* Washington, DC: Author.

Office of Technology Assessment, U.S. Congress. (1988). *Power on! New tools for teaching and learning.* Washington, DC: Author.

Office of Technology Assessment, U.S. Congress. (1989). *Linking for learning: A new course for education.* Washington, DC: Author.

Panos, N. (1981). *The effects of "Sesame Street" on pre-school learning and behavior*. South Bend, IN: Indiana University.

Puma, M. J., Chaplin, D. D., & Pape, A. D. (2000). *E-Rate and the digital divide: A preliminary analysis from the integrated studies of educational technology*. Washington, DC: The Urban Institute.

Revenaugh, M. (1999). All about the E-Rate. *Educational Leadership, 56*(5), 36-38.

Rice, M. L., Huston, A. C., Truglio, R., & Wright, J. C. (1990). Words from "Sesame Street": Learning vocabulary while viewing. *Developmental Psychology*, *26*(3), 421-428.

Rothenberg, D., & Morgan, R.P. (1975). *Case studies of innovation in the educational service sector*. St. Louis, MO: Center for Development Technology, Washington University.

Sanchez, R., & Lane, C. (1996). Star Schools: A constellation of resources. *Principal*, 76, 46-47.

Software & Information Industry Association. (n.d.). Federal investment in K-12 education technology providing critical funding for the integration of technology into teaching and learning. Retrieved on July 15, 2008, from http://www.siia.net/govt/docs/pub/ed_brief_fedinvestment.pdf

Staihr, B., & Sheaff, K. (2001, February). The success of the "E-Rate" in rural America. *The Main Street Economist*, 1-4.

Suppes, P. & Fletcher, J. D. (1974). Computer-assisted instruction in mathematics and language arts for deaf students. Proceedings of the National Computer Conference, Chicago IL. Montvale, NJ: AFIPS Conference Proceedings.

Swinton, S.S., Amarel, M., & Morgan, J.A. (1978). *The Plato elementary demonstration educational outcome evaluation. Final report: Summary and conclusions*. Urbana, IL: University of Illnois.

Tolbert, L., & Theobald, P. (2006). Finding their place in the community: Urban education outside the classroom. *Childhood Education*, *82*(5), 271-274.

Tushnet, N. C., Manuel, D. M., Millsap, M. A., Chase, A., Garnette, C., & Katzenmeyer, C. (1994). The Star Schools distance-learning program: Results from the mandated study. Paper for the American Educational Research Association Annual Meeting, New Orleans, LA. Los Alamitos, CA: Southwest Regional Laboratory.

U.S. Department of Education. (1997). Learning beyond the classroom. *Building knowledge for a nation of learners: A framework for education research.* Retrieved on July 15, 2008, from http://www.ed.gov/offices/OERI/RschPriority/plan/chap2g.html

U.S. Department of Education. (2003). The integrated studies of educational technology, Office of Educational Technology [Web page]. Retrieved on October 11, 2008, from http://www.ed.gov/Technology/iset.html#tlcf

U.S. Department of Education. (2006). Star Schools program: Eligibility [Web page]. Retrieved Aug. 5, 2008, from http://www.ed.gov/programs/starschools/eligibility.html

U.S. Department of Education. (2008). Star Schools program: Purpose [Web page]. Retrieved Aug. 5, 2008, from http://www.ed.gov/programs/starschools/index.html

Van Meer, E. (2003, November 5). PLATO: From computer-based education to corporate social responsibility. *Iterations: An interdisciplinary journal of software history,* 2, 1-22.

Who wants to live on Sesame Street? (1973, Mar. 24). *Science News*, 103, 183.

Wright, J. C., Huston, A. C., Murphy, K. C., St. Peters, M., Pinon, M., et al. (2001). The relations of early television viewing to school readiness and vocabulary of children from low-income families: The Early Window project. *Child Development*, *72*(5), 1347-1366.