Chapter 7

State of Research and Development in Educational Technology

Child watcher of Sesame Street: Dr. Palmer records the viewing habits of two intent preschoolers with a simple set-up including a TV set which receives pretaped material and a slide projector which exhibits fresh still photographs every few seconds

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Support of basic research and development (R&D) in most fields of technology has traditionally been a function of the Federal Government. The Government has also funded applied research when its purpose was to advance certain national goals or to serve the mission needs of Federal agencies. R&D not only generates important new knowledge about educational technology, but, when done in academic centers, it can also provide an instructional base with which to train experts needed to create effective instructional materials.

Findings

- Gaps in our knowledge about information technology could limit our ability to use it effectively, and, if leading to its inappropriate implementation, could negatively affect both the learners and the institutions using the technology.
- The Department of Defense (DOD) now provides the bulk of R&D support in the field of learning technology.
- Civilian agency funding for R&D in learning technology, the majority of which comes from the Department of Education, has fallen precipitously from a temporary short-term peak in the late 1960's.
- If Congress wanted to stimulate effective educational applications of information technology, it would have to undertake or foster a substantial program for R&D. The Secretary of Education has stated that a program of research support is a major administrative priority, and that such a program has been built into the 1983 budget request.
- Given the number of agencies that have an existing or potential interest in R&D in this area, the Federal Government may want to coordinate these efforts so as to allow for a greater exchange of information and a more efficient and effective allocation of responsibilities. The responsibility for such coordination could be vested in a single agency, or existing interagency group, or an agency especially established for that purpose.
- In light of the tight Federal budget and the potential interest of the private sector in educational technology, mechanisms for leveraging Federal support to stimulate industry and foundation funding for R&D might be investigated.

Introduction and Background

Since the 1950's, R&D in educational technology has been funded by the Federal Government, by foundations, by the business community, and, in some cases, by all three in collaboration with one another. To date, the role of the Federal Government has been to provide initial and limited ongoing support that might serve to attract other sources of funding. The Federal agencies most deeply involved have been the National Science Foundation (NSF), the Department of Education (OE) (formerly a part of the Department of Health, Education, and Welfare), and DOD.

Acting on a legislative mandate to foster computing in science education, NSF, through its Science and Engineering Education Directorate, has funded a variety of computer-assisted learning research efforts, including the initial development of the PLATO instructional system at the University of Illinois in 1959.[1] Grants have been made to provide initial and ongoing support of educational television projects such as NOVA and 3-2-1 Contact, both of which have received worldwide acclaim and have served as models for programs in other nations. NSF has also funded efforts to determine how computer-controlled video disk may be used to enhance science education in physics and biology. It has issued grants for science news coverage broadcast on 227 public radio stations, and has sponsored early satellite experiments. In addition, in fiscal years 1980 and 1981, NSF and the National Institute of Education (NIE) jointly funded "Mathematics Education Using Information Technology," a program that, through the use of small grants, has encouraged the development of computer software for use in mathematics curricula.

Support of educational technology R&D dates back to the early 1960's with the inception of the Educational Broadcast Facilities Program, which was designed to improve the national capabilities of public radio and television. In fiscal year 1968, OE funding of the Children's Television Workshop, along with that of the Carnegie and Ford foundations, led to the creation of Sesame Street and The Electric Company, two programs that have won international recognition. Computer-based instructional materials on the elementary, secondary, and college levels for target populations such as the handicapped, video disks for classroom use, and experiments with educational broadcasts via satellite, have all been undertaken with OE support.

DOD has also made significant contributions to the R&D of educational technologies. Faced (since the 1970's) with a greater need to provide basic skills instruction to recruits, to train individuals to operate more complex equipment, and to deliver instruction in the field in multiple locations, the military has placed renewed emphasis on developing applications of technology. Through the tri-services of the Army, the Navy/Marine Corps, and the Air Force, DOD has, since then, sponsored R&D projects in the areas of:

- computer-based education;
- computerized-adaptive testing;
- simulation and gaming;
- video disk technology;
- artificial intelligence;
- instructional development/authoring aids; and
- job-oriented basic skills training.[2]

Other agencies that have made grants on a periodic basis include the National Aeronautics and Space Administration (health/education satellite projects in the 1970's), the Environmental Protection Agency, the Department of Interior, the National Institutes of Health (contributions to NSF grants in science broadcasting), and the Department of Commerce (telecommunications projects jointly funded with OE).

In recent years, the Federal Government's involvement in and support for educational hardware, software, and basic research has decreased. A brief review of the current trends in R&D, and of the comparative roles that the public and private sectors have played in this area will contribute to an understanding of the causes and potential impact of declining Federal support.

[1] The National Science Foundation Act, Public Law 81-507.

[2] B. K. Waters and J. H. Laurence, *Information Technology Transfer From Military R&D to Civilian Education and Training*, report prepared by Human Resources Research Organization for the Office of Technology Assessment, January 1982.

Changing R&D Climate

Since 1980, the industrial sector has provided more funding for all types of R&D activities than the Federal Government. Recent projections indicate that, in 1982, industrial funding will rise to $37.7 billion, which represents an 11.4-percent increase over 1981, and 48.6 percent of the total $77.6 billion available for support of R&D. Federal funding will rise to $37 billion, an increase of 13.3 percent over 1981, and 47.7 percent of the total R&D expenditure for 1982. Academic institutions are expected to contribute $1.7 billion (2.2 percent of total), while other nonprofit groups will provide $1.1 billion (1.5 percent of total). Industry will perform 70.8 percent ($55 billion) of all R&D, while the Federal Government will carry out only 13 percent ($10.1 billion-a large portion of this defense-related). Academic institutions will perform 12.5 percent of all R&D ($9.7 billion) and other nonprofit groups 3.6 percent ($2.8 billion). Thus, although once at the center of basic research and R&D efforts, colleges and universities will now receive only one-fifth of the moneys earmarked for these activities.[3]

The Economic Recovery Tax Act of 1981 may improve the universities' chances of receiving basic research grants from industry, since it allows companies to treat such grants as qualified research expenses on which 25 percent tax credits may be claimed. The act is also expected to encourage corporations to donate scientific equipment to universities for R&D use.[4] Some firms are also establishing long-term working relationships with universities for the performance of basic and applied research. These arrangements are economical to them because of lower labor costs. In addition, faced with increased international competition, firms are more interested in tapping the reserves of university research talent.[5]

Shifts in the source of funding of and in the majority of performers of R&D from the public and nonprofit sectors to the private sector have occurred after a period in which the business community (especially manufacturing industries) had sharply reduced involvement in basic research and long-term R&D projects. As reasons for these changes, business leaders cite increased Government regulation, increased rates of inflation that make return on long-term investments more questionable and an increased concern for the short-term effects of R&D on profits. As a consequence, many companies have focused their R&D efforts on short-term, low-risk, incremental projects.[6]

Industrial R&D funding has also been affected by the availability of R&D tax shelters —limited partnerships formed to finance new product development. These provide companies with virtually free money until their products can be marketed. But these shelters are used only in selected parts of the country, and then, only in newer firms willing to take greater risks.[7]

To complicate matters further, a severe shortage of scientists and engineers, projected to last through the 1990's, has had a tremendous impact on U.S. R&D efforts in all sectors. The most alarming effects are seen in the faculties of colleges and universities, where, at the start of the 1980-81 academic year, approximately 10 percent of the teaching/research engineering positions remained vacant. Only 5 percent of engineering undergraduates now choose to pursue doctorates in contrast to 11 percent in the 1970's. Those who earn higher degrees are electing to start careers in industry, where salaries are considerably higher and equipment and resources are more plentiful. In a recent NSF study of engineering schools conducted by the American Council on Education, 35 percent of the respondents reported that, because of shortages in personnel, their institutions had to cut back research

[3]J. J. Duga, *Probable Levels of R&D Expenditures in 1982: Forecast and Analysis* (Columbus, Ohio: Battelle Laboratories, December 1981).

[4]R. W. Wood, "Research and Development Expenditures Under the Economic Recovery Tax Act," Taxes, November 1981, pp. 777-783.

[5]"Industry Funding of Research at Schools Grows as Firms Find the Work a Bargain," *Wall Street Journal*, vol. 102, June 24, 1980, p. 14.

[6]E. Mansfield, "How Economists See R&D, *Harvard Business Review*, November-December 1981, pp.. 98-106.

[7]"R&D Tax Shelters Are Catching On," *Dun Business Month*, pp. 86-87.

efforts, increase faculty teaching loads, and curtail certain courses when demand for engineering talent, especially in high-technology industries is at an all-time high.[8]

[8]F. J. Atelsek and I. L. Gomberg, *Recruitment and Retention of Full-Time Engineering Faculty, Fall, 1980* (Washington, D. C.: American Council on Education, October 1981).

The shift in sources of funding and in the amount of R&D performed by industry, as well as the critical shortages of scientists and engineers, have weakened the ability of the United States to compete in worldwide R&D activities, and have hampered U.S. manufacturing firms from effectively competing in international markets.

Federal Funding

Even more critical than the state of R&D in general is the current state of R&D for educational technology. Analyses made in March 1981 of the Federal budget proposals for fiscal year 1982 indicate that education and research programs, which accounted for approximately 4 percent of all Federal spending in 1980, will constitute 13 percent of the total spending reductions. Even with the approved fiscal year 1982 funding levels established by Congress in December 1981, Federal expenditures for education and research in constant dollars will be well below actual 1980 levels. In 1982, spending will be about 20 percent below 1980 levels, and, by 1984, it may fall by as much as 53 percent below.

Federal support represents a significant portion—in some cases up to 25 percent—of funds that the nonprofit sector, including universities and other educational institutions, uses for operations and programs. Federal support grew over the past 20 years, as the Federal Government came to rely increasingly on nonprofit organizations to deliver and/or evaluate federally funded programs. While foundations and corporations have been generous with funding, their contributions will probably not make up for reduced Federal involvement, especially since nearly one out of every four of the dollars eliminated from the Federal budget for fiscal year 1982 would have gone to a nonprofit organization.[9]

‘L. A. Salamon with A. J. Abramson, *The Federal Government and the Nonprofit Sector: Implications of the Reagan Budget Proposals* (Washington, D. C.: The Urban Institute, May 1981).

Private Funding

Foundations have also played an important educational role by financing coremissions and studies, funding development and demonstration projects, organizing conferences, and supporting think-tanks. Recently, the Sloan Foundation supported a conference at which educators and representatives of industry discussed how mathematicians might be retrained for careers in applied computer science in order to alleviate severe occupational shortages. The Carnegie Foundation has participated in jointly funded broadcasting projects produced by NSF. The Hewlitt Packard Foundation has expressed an interest in supporting NSF-sponsored science programs for commercial television. Plans for the project may be jeopardized, however, because of funding reductions within NSF's Office of Science and Engineering Education (formerly the Science and Engineering Education Directorate).

In the past, selected companies have been generous in their support of education. Some have participated with Federal and State governments in jointly funded computer-based learning projects as well as other technology-based activities. Although it is difficult to estimate the amount of corporate support for educational technology, education has always been a high-priority area for support. The Annual Surveys of Corporate Contributions, a series conducted by the Conference Board for the years 1978, 1979, and 1980, shows that contributions made to educational institutions and organizations for a wide variety of purposes have increased from $256.3 million to $375.8 million-from 37 percent of the total contributions of reporting companies in 1978 ($693.2 million) to 37.7 percent of those firms reporting in 1980 ($994.6 million) .'" Support of education measured as a percentage of pretax net income has increased from 0.179 in 1978 to 0.220 in 1980. " However, if funding for such activities is to remain at the 1980 levels (in constant dollars), private donations will have to increase substantially in all program areas, including education and research. An Urban Institute study of how the Federal budget cuts, as proposed in March 1981, would affect the educational programs of nonprofit institutions showed that they will receive $0.7 billion dollars less in income from public sources, and they will receive $7.3 billion from private sources. To maintain the existing value of private support, contributions from the private sector must increase by 17.9 percent:

> . . . private giving would have to increase by 144 percent between 1980 and 1984 in order to keep up with inflation and makeup for revenue lost to nonprofit organizations as a consequence of the budget cuts. By comparison, however, during the most recent five-year period, private giving in practice increased only 38 percent. In other words, in order for private nonprofit organizations to hold their own . . . even using (administration) inflation assumptions, private giving would have to increase four times faster between 1980 and 1984 than it did over the five-year period just ended. [12]

There is evidence that corporations are willing to increase their support of educational, arts, and social service programs affected by Federal budget reductions. Corporate giving clubs are being organized by business leaders in various part of the country to ensure that companies set aside up to 5 percent of pretax revenues for this purpose. However, according to Internal Revenue Service records, only about 35 percent of the Nation's 1.5 million profit-reporting firms claimed any charitable deductions in 1977 (latest figures available), with only 58,000 taking advantage of the full 5 percent allowable deduction. Furthermore, most of these donations went to support local community projects rather than national programs. Few, if any, of these donations carry with them the requirement that projects' results be widely disseminated.[13]

Hopefully, the founding of such clubs will offset the potential negative effect that the provisions of the Economic Recovery Tax Act of 1981 might have on charitable donations. Because the act allows faster depreciation and more investment tax credits, it will have the effect of reducing taxable income.[14] A recent Conference Board survey of trends in business volunteerism in the largest U.S. manufacturing, service, financial, and transport firms indicated that, for a variety of reasons—among them current economic conditions, companies are not redirecting or expanding their program interests in response to Federal budget reductions. In fact they may not be able to give as much in the future as they have in the past.

[10]It is important to note that response rates to the *Annual Survey of Corporate Contributions* varied for the years cited: 1978–759 companies; 1979–786 companies; 1980–732 companies. Annual tabulations of corporate contributions published by the American Association of Fund-Raising Counsel, show that giving levels for 1980 and 1981 were $2,7 billion and $3.0 billion respectively.

“Conference Board and the Council for Financial Aid to Education, *Advance Report From the Annual Survey of Corporate Contributions, 1980 (New* York: The Conference Board, Inc., 1981).

[12]Salamon and Abramson, op. cit.

[13]" How Corporate 'Clubs' Fill the Gap in Giving, " *Business Week*, Nov. 23, 1981, pp. 54 F-55.

[14]"More Tax Incentives for R& D," Business *Week*, Sept. 7, 1981, pp. 74L,P.

Some respondents said that they thought that a lower corporate tax rate may well discourage giving. Representatives of 6 of the 10 companies said that they do not expect to lend more executives to nonprofit institutions in place of, or in addition to, direct contributions.[15]

[15]E. P. McGuire and N. Weber, *Business Volunteerism: Prospects for 1982* (New York: The Conference Board, Inc., January 1982).

Federal Commitment to Educational Technology R&D, Fiscal Year 1982

Approved congressional budget levels and conversations with budget and program officers in NSF, OE, DOD, and other agencies, suggest that the Federal investment in educational technology R&D in fiscal year 1982 will amount to $273.915 million, $256 million of which will be utilized by the tri-services (Army, Navy/Marine Corps, and Air Force) as a part of the Training and Personnel Systems Technology Program (TPST). Ongoing program elements of TPST, according to which specific projects are funded, are listed in table 18; selected project topics funded within these program elements are listed by service branch in table 19.

Of the remaining $17.915 million (non-DOD funding), the largest percentage-an estimated $5.55 million-will go to support computer research, including software development in science, math, reading, and written communications. Educational television projects will receive the second highest amount-an estimated $5.236 million. The remaining $7.129 million will be used to support educational applications of video disk and teleconferencing and to develop special technology applications for educating the handicapped.

Breakdowns of R&D funding within NSF, OE, and DOD and estimates of the dollars set aside for educational technology R&D projects in fiscal year 1982 are given in tables 20, 21, and 22. NSF has provided $4.536 million—0.457 percent of the agency's total projected R&D expenditure ($991 million) -to grants of this type. Educational technology projects w-ill be funded to varying degrees within six program areas in OE. The total projected amount is $13.379 million, 12.45 percent of the ap-

Table 18.— Department of Defense Training and Personnel Systems Technology R&D Program Elements and Funding Levels—Fiscal Year 1981-82

	Dollars in millions	
Program element	Fiscal Year 1981	Fiscal year 1982
Army		
Training, personnel, and human engineering	$3.9	$4,0
Human factors in systems development	7.0	8.7
Human performance effectiveness and simulation	3.2	3.5
Manpower, personnel, and training	6.2	6.0
Nonsystem training devices technology.	2.7	2.7
Synthetic flight simulators	3.9	7.8
Manpower and personnel	3.4	4,7
Nonsystem training devices development	0.0	1.4
Human factors in training and operational effectiveness	1.9	3,1
Education and training	7.8	9.6
Training and simulation.	1.5	2.2
Synthetic flight training systems.	0.6	8.3
Nonsystem training devices engineering	12.2	12.9
	$54.3	$74.9
Navy *and Marine Corps*		
Behavioral and social sciences	7.7	8.8
Human factors and simulation technology	5.9	6.5
Personnel and training technology	5.7	6.4
Human factors engineering development.	2.9	3.1
Manpower control system development	3.1	2.8
Man-machine technology	0.0	0.0
Education and training	4.8	3.7
Navy technical information presentation system	1.8	1.3
Marine Corps advanced manpower training system	1,3	1.5
Training devices technology.	6.0	8.0
Training devices prototype development	13.9	10.4
Prototype manpower/personnel systems	1,1	5.0
Air warfare training devices	13.7	27.9
Surface warfare training devices	34.4	41.7
Submarine warfare training devices	2.9	4,6
	$105.2	$131.7
Air *Force*		
Human resources	4.8	4.9
Aerospace biotechnology	8.2	8.8
Training and simulation technology	12.9	14.2
Personnel utilization technology	5.3	5.5
Advanced simulator technology.	3.2	2.2
Innovations in education and training	1.7	2.5
Flight simulator development.	5.5	11.3
	$41,6	$49.4
Total	$201.1	$256.0

SOURCE Department of Defense, Office of the Undersecretary for Research and Engineering, compiled January 1982

Table 19.—Training and Personnel Systems Technology R&D Program: Selected Project Topics— Fiscal Year 1981-82

Army

Man-computer communication techniques
Application of video disk to tactical training and skill
Qualification testing
Technology-based basic skills and individual skills development systems
Computer-based maintenance training aids
Integration of microwave and computer technologies
Computer-based maintenance training aids

Computer-based maintenance training and other computer-based instructional systems
Individualized automated training technique
Computer literacy (teaching computer programing skills)
Advanced training technology development
Advanced voice interactive systems development
Computer-assisted design and evaluation systems
Computerized personnel acquisition system development
Utilization of computer graphics for maintenance instruction
Computer-based basic skills instruction
Advanced computer-aided instruction for complex skills
Experimental, technology-based combat team training systems
Computerized course authoring systems
Computer-based speech recognition and synthesis

Human-computer combinations
Computer-aided technical instruction
Advanced visual technologies
Computer-based maintenance aids

SOURCE Department of Defense, Office of the Undersecretary for Research and Engineering

proved R&D funding level of $107.4 million. Of $19.9 billion approved for DOD R&D funding, 1.28 percent, or $256 million, will be spent on training and simulation devices, computer instructional software development, and other technology-based projects. Government-wide commitment levels to educational technology projects are broken down by agency in table 23.

Table 20.— National Science Foundation R&D Budget, Fiscal Year 1982 for Selected Program Areas

Program area	Approved R&D funding level	Funds for education technology R&D	Percent of program total
Mathematical and Physical Sciences . .	$273 million	0	0
Engineering and Applied Sciences	$92 million	0	0
Scientific, Technological, and International Affairs and Cross-Directorate Programs	$40 million	0	0
Science Education, Development, and Research[a]	$21 million	Estimated $2.2 million computing in education. Estimated $2.336 million science broadcasting.	21 .60/0
Subtotal, selected program areas. . . .	$426 million	$4.536 million	10.6
Total (all R&D within agency)	$991 million	$4.536 million	0.4570/0

[a]Legislative mandate to foster computing in science education

SOURCE American Association for the Advancement of Science, National Science Foundation, and Off Ice of Technology Assessment

Table 21 .—Department of Education R&D Budget, Fiscal Year 1982 for Selected Program Areas

Program area	Approved R&D funding level	Funds for education technology R&D	Percent of program total
National Institute of Education.	$53.4 million	$1.3 million (est.)	2.430/.
National Institute for Handicapped Research.	$28.6 million	$0.2 million (est.)	6.99
Bilingual Education.	$6,0 million	o	0
Handicapped Research Innovation & Development	$7.2 million	$0.9 million	12.5
Vocational Educational Programs of National Significance	$5.5 million (est.)	o	0
Educational Technology.	$6.679 million	$6.679 million	100
Special Education Resources		$1.8 million	
Fund for the Improvement of Postsecondary Education	$10 million	$2.5 million	40
Total (all R&D within agency)	$107.4 million	$13.379 million	12.450/o

SOURCE: Department of Education and Office of Technology Assessment.

Table 22.— Department of Defense R&D Budget, Fiscal Year 1982 for Selected Divisions

Department	Approved R&D funding level	Funds for education technology R&D	Percent of program total
Army	$3.6 billion	$74.9 million[a] (est.)	20.80/o
Navy and Marine Corps	$5.9 billion	$131.7 million[a] (est.)	2.23
Air Force.	$8.9 billion	$49.4 million[a] (est.)	5.55
Defense agencies	$1.7 billion	o	0
Total (all R&D within department) . . .	$19.9 billion	$256.0 million	1.280/o

[a] Additional R&D efforts may exist that are not captured within training and personnel technology program data base.

SOURCE: American Association for the Advancement of Science, Department of Defense; and Office of Technology Assessment

Table 23.—Projected Federal Expenditures for Educational Technology R&D, Fiscal Year 1982

Department	Projected expenditure educational technology—R&D	Total R&D budget (approved levels)
National Science Foundation	$4.536 million (est.)	$991 million
Department of Education	$13.379 million (est.)	$107.4 million
Department of Defense	$256 million (est.)	$19.9 billion
Total	$273.915 million (est.)	$20.99 billion

SOURCE: Office of Technology Assessment and American Association for the Advancement of Science,

Discontinued and Consolidated Projects

Research on the educational applications of satellite technology will not be supported by the Federal Government in fiscal year 1982, with the exception of one small project sponsored by NIE and conducted by a regional educational laboratory. Support for Federal telecommunications research and demonstration has been discontinued, except for two projects that will receive some funding for fiscal year 1982. The Deafnet Telecommunications Model, the product of a 3-year effort that involved modifying existing electronic mail technology, will be disseminated to potential users under a $300,000 grant. OE's Division of Educational Technology (Office of Educational Research and Improvement) will provide $1.1 million to support "Project Best, " a series of teleconferences designed to help officials in 45 States to understand the potential of the technology. The National Telecommunications Program established by Congress in 1976 to "promote the development of nonbroadcast telecommunications facilities and services for education and other social services" was not reauthorized for fiscal year 1982. It would also appear that a 3-year project that was designed to demonstrate the use of teletext in the United States and that was jointly sponsored by OE, NSF, the National Telecommunications Information Administration, and the Canadian Government, will be discontinued. (In fiscal year 1981, OE contributed $1 million to the effort.) The Television and Radio Program authorized by the Emergency School Aid Act of 1972 under which grants to reduce minority isolation in the media were made, as well as the Basic Skills and Technology Program authorized by the Education Amendments of 1978, designed to encourage research into the application of technology to problems in basic skills instruction, have been consolidated with other programs into a State educational block grant at overall reduced levels of funding. (In 1981-82, the combined support for these two programs amounted to $6.5 million.) OE support for video disk development will not be pursued due to lack of funds. However, several video disk projects included within a group of multiyear contracts previously awarded by OE (an estimated $20 million investment for all such contracts) are scheduled for completion in fiscal year 1983 and fiscal year 1984.

Continuing Projects

Multiyear grants that will continue to be funded in fiscal year 1982 are listed by agency in table 24. Seven ongoing educational television projects will be supported by OE. The use and adaptation of technology for the handicapped and for special education will be encouraged. And, through the Fund for the Improvement of Postsecondary Education, grants will be made to local educational projects that use teleconferencing, computer-aided instruction, video disk, and other forms of technology (estimated $25.7 million). NSF will continue its science broadcasting program ($2.336 million) and will review its computer-based education projects and others similar to them ($2.2 million). Support has been discontinued for the Mathematics Education Using Information Technology Program, designed to encourage computer courseware development, and previously supported jointly with OE. To date, NSF has contributed $3.5 million, and NIE has contributed $0.5 million to this project. In fiscal year 1982-83, NIE will provide $0.6 million in support.

Information about which specific projects will be funded in this fiscal year under elements of DOD's Training Personnel and Systems Technology Program is still unavailable. However, some idea about the nature of these activities can be gained by looking at selected tasks that are under way at the Army Research Institute (ARI). ARI will continue development of a hand-held computer for vocabulary building, a computer-assisted career counseling system, and a special data management system that will integrate video disk technology with a computer for basic skills instruction (estimated at $2.25 million).

Table 24.—Continuation Grants for Educational Technology R&D, Fiscal Year 1982[a]

Program	Grant description	Funding level
Department of Education		
Division of Educational Technology (Office of Educational Research and Improvement	**Microcomputer Software**	**$2.25 million**
	Development: Elementary grades (3 yrs. funding at $150,000 per project) Ohio State: mathematics; development and testing in 25 schools by fiscal year 1963. Wycatt: reading; Bolt, Beranek and Newman: written communication composition	
	Video disk	
	University of Nebraska: development of Spanish-English dictionary and microcomputer software. American Institute of Research: video disk for music and math curricula for elementary grades; 45 site demonstrations and electronic mail component.	$0.225 million
	Teleconferencing	$0.250 million
	"Project Best:" assistance to officials in 45 States in understanding potential of technology; electronic mailbox component; 8 teleconferences.	$1.1 million
	Television	
	Seven projects: (selected grants highlighted) "3-2-1 Contact:" production funds to Children's Television Workshop ($1 million). "Power House:" health and nutrition—economically disadvantaged minority youth ($3.5 million). "Kids:" program for elementary grades on radio broadcasting ($1 million).	$16.175 million
National Institute for Handicapped Research	Adaptation of educational technology for use by handicapped	**$0.2 million** (est.)
Special Education Resources	Deaf net Telecommunications Project—model dissemination ($0.3 million). Line 1 Caption Broadcasting Program ($1.5 million).	$1.8 million (est.)
Handicapped Research—Innovation Development	Technology Utilization Project	$0.9 million (est.)
National Institute of Education	"Mathematics Education Using Information Technology:" (until fiscal year 1982-83 jointly funded with NSF; $0.6 million). Computer courseware development "Calculator Information Center" ($0.1 million). "Computer Software Clearinghouse" ($0.2 million). Portion of Regional Educational Laboratories budget utilized for educational technology projects: courseware development; satellite telecommunications project (est. $0.4 million).	$1.3 million (est.)
Fund for the Improvement of Postsecondary Education	Educational television, teleconferencing, computer-aided instruction, and video disk (local projects)	$1,5 million (est.)
National Science Foundation		
Office of Science **and Engineering Education**	Computer-based education, CAD/CAM[b] education, and other projects currently up for review.	$1.7 million (est.)
	science Broadcasting	$2.336 million
	Prism Productions, Inc., "How About:" 90 second science series for commercial television (syndicated to 140 stations—jointly funded with General Motors Research Labs; NSF contribution: $0,208 million). Children's Television Workshop, "3-2-1 Contact:" science programing; National Public Radio, "Science Information on Public Radio:" establishment of science production capabilities and provision for science coverage for distribution to 227 public radio stations ($0.198 million).	
Department of Defense		
Army	See tables 18 and 19 for program elements and project topics.	$73.5 million
Navy and Marine Corps	See tables 18 and 19 for program elements and project topics	$131.7 million
Air Force	See tables 18 and 19 for program elements and project topics.	$49.4 million
Total		$284.336 million

[a]Some funded with fiscal year 1980 and fiscal year 1981 moneys.
[b]CAD/CAM-Computer-assisted design/computer-assisted manufacture.

SOURCE: Office of Technology Assessment.

New Grants for Fiscal Year 1982

A breakdown of the funds that have been tentatively earmarked or committed for new projects within OE, NSF, and DOD is shown in table 25. Approximately $6.8 million are available, $5.4 million within OE. The Army has established a new Non-System Training Devices Development Program with an initial budget of $1.4 million. NSF will fund only one new project in fiscal year 1981—a $0.5 million effort to foster innovative ideas for using computers in science education. The project was conceived after NSF had been approached by several manufacturers who offered to provide free microcomputers for experimentation in educational institutions.

A revealing analysis of Federal support of R&D for educational technology in fiscal year 1981 is shown in table 26, which presents estimates of funding levels for particular types of technology. Educational television will receive more money than any other form of technology-an estimated $21.411 million, a sum that includes grants for local demonstrations. From fiscal year 1968 through fiscal year 1980, the Children's Television Workshop received grants from OE totaling $46.3 million for the development and production of Sesame Street and The Electric Company-an average of $3.56 million per year.[16] If the increased costs of television production and general inflation are taken into account, the $21.411 million Federal support level for fiscal year 1982 will clearly be insufficient to maintain the same volume of programing that previously existed. This year, OE's Office of Educational Research and Improvement (Division of Educational Technology) has plans to award only

16A. A. Zucker, *Support of Educational Technology by the U.S. Department of Education: 1971-1980* (Washington, D. C.: U.S. Department of Education, February 1982).

Table 25.—New Grants for Educational Technology R&D, Fiscal Year 1982

Program	Grant description	Funding level
of Education		
Division of Educational Technology	Educational television projects	$2.9 million (est.)
National Institute for Handicapped Research	Adaptation of educational technology for use by handicapped; other topics to be identified.	
	Bank Street College: 26- to 15-minute programs for ITV or ETV use, plus computer game software, computer graphics, and video disk application.	$1 million (est.)
	"Careers in Electronics and Computers" (working title): two 60-minute programs that focus on opportunities for young people and displaced workers.	
Special Education Resources	None	0
Handicapped Research—innovation and development	Technology utilization projects	0
National Institute of Education	None	0
Fund for the Improvement of **Postsecondary Education**	Based on proposals received **to date (40 percent are for education technology projects**	$1 million (est.)
National Science Foundation		
Science and Engineering Education Office	"Gift Program:" (in response to gift of microcomputers offered by two producer companies) foster innovative ideas for using computers in science education.	$0.5 million
Department of Defense		
Army	Nonsystem Training Devices Development	$1.4 million
Navy and Marine Corps	None	0
Air Force	None	o
Total		$6.8 million (est.)

SOURCE" Office of Technology Assessment

Table 26.—Federal R&D Funding for Educational Technology Fiscal Year 1982 By Type of Technology[a]

Technology	Agencies funding	Funding level
Computer-based instruction	National Science Foundation; Department of Education; Department of Defense	million (est.)
Educational television	Department of Education	$21.411 million
Teleconferencing	Department of Education	$1.1 million (est.)
Video disk	Department of Education	$0.975 million (est.)
Electronic mail	Department of Education	$0.3 million (est.)
Satellite	Department of Education (Funding of Regional Laboratories)	million (est.)
Calculators	Department of Education	$0.3 million (est.)
Other		$4.55 million (est.)
Total		$34.236 million (est.)

[a] Includes multiyear projects funded with fiscal Year 1980 and fiscal Year 1981 moneys.

SOURCE: Office of Technology Assessment.

two new educational television grants that amount to $2.9 million. Computer-based instruction (including software development) is the only technology that will be supported in fiscal year 1982 by all three Federal agencies (at a total level of $5.55 million). Other technologies, such as video disk, electronic mail, and calculators, will each receive between $0.2 million and $0.3 million in Federal support, all of it coming from OE.

Federal Support for Educational Laboratories

With the Cooperative Research Act of 1963 and the Elementary and Secondary Education Act of 1965, the U.S. Office of Education established regional centers and laboratories for educational research to focus efforts and to encourage experimentation under controlled conditions. In fiscal year 1982, NIE will provide $28 million for these centers and laboratories. Of this amount, about $335,000 will be used to support educational technology projects. The Wisconsin Center for Educational Research at the University of Wisconsin at Madison, Wis., will investigate possible uses of microcomputers in problem-solving and language skills instruction. The University of Pittsburgh's Learning Research and Development Center has initiated small curriculum software development projects in developmental reading, writing, and mathematics. Through a communications skills project, the Southwest Regional Laboratory hopes to develop microcomputer software for student use in generating, manipulating, and editing text in an interactive mode. Some of the funding for educational technology R&D projects comes from the States, as do some of the funds to support the Northwest Regional Educational Laboratory educational satellite project for R&D dissemination.

Educational Technology R&D Support by Other Nations

While the U.S. Government is reducing its commitment to develop new applications of information technology in education, a number of other countries are planning or initiating major programs. Some have succeeded in attracting U.S. researchers as major participants.

France

In January 1982, France announced plans to establish a World Center for Computer Science and Human Resources for the expressed purpose of designing personal computer systems for use in training and education projects in industrialized and Third World countries. With an initial annual operating budget of $20 million, the center staff has tentative plans to develop computer-based education projects in Senegal, Kuwait, Ghana, and the Philippines. The center will most probably receive additional financial support from those countries. Programs to retrain workers whose jobs have been eliminated through automation are also under consideration.

Some see the establishment of the center as evidence that the French Government regards the computer as an important agent of social change and that it views its development as an important factor in determining how well the French will compete with the United States in the field of microelectronics.[17] Although the center's board of directors will have international representatives, at least nine French cabinet ministers will be among its members.[18] The chairman of the World Center will report directly to President Francois Mitterand, an indication of the importance that the French Government attaches to the project.

Two U.S. scientists have accepted positions with the center. Nicols Negoponte, a professor of computer graphics at the Massachusetts Institute of Technology (MIT), will assume the post of director. Seymour Papert, founder of MIT's artificial intelligence program and developer of the computer programming language LOGO, will serve as its chief scientist.

Testifying on May 19, 1982, before the Subcommittee on Investigations and Oversight and the Subcommittee on Science, Research, and Technology of the House Committee on Science and Technology, Jean Jacques Servan-Schreiber, chairman of the World Center, described it as the first of a network of such facilities that will focus on human resource development through application of computer technology. He expressed the hope that the United States would establish the next such center, encourage the funding of others, and cooperate with France in " . . . the implementation of a policy aimed at the stimulation of worldwide economic activity and employment. "[19]

European Commission

The European Commission, the independent policy-operating body of the European Community, plans to launch a 10-year, $1.6 billion program to aid research in computer-related technology. Funding will come from the commission, from the industrial sector, and from other sources. These funds will be distributed as grants to European research groups, private laboratories, and universities for concentrated efforts in such areas as office technology, factory automation, software, advanced microelectronic chips, and artificial intelligence. European researchers and business representatives will discuss the project during 1982. Plans call for the program to be initiated before the end of 1983.[20]

United Kingdom

Britain believes that its future role in international markets will be largely affected by the investments it makes now in fostering the development of information technology. With this in mind, the British Government is establishing a comprehensive policy for information

[17]"Micros Are This Year's Paris Fashion, " New *Scientist* Feb. 2.5, 1982, p. 486.

[18]M. Schrage, "France Plans Computer World Center, " *Washington Post*, Jan. 28, 1982.

[19]J. J. Servan-Schreiber, testimony of Jean Jacques Servan-Schreiber, before the Subcommittee on Investigations and Oversight and Subcommittee on Science, Research, and Technology, Committee on Science and Technology, U.S. House of Representatives, May 19, 1982.

[20]"EEC Stakes 855 Million on Tomorrow's Computers, " *New Scientist*, Jan. 7, 1982, p. 5.

technology that will have the following key elements:

- provision of a national telecommunications network;
- the development of a statutory and regulatory framework designed to encourage further growth of information technology products and services;
- initiation of actions to create an awareness of the inherent advantages of information technology and to stimulate interest in utilizing new services and equipment; and
- direct support to the development of new products and techniques.

A Ministry for Information Technology has been created within the Department of Industry, to serve as the point of coordination for all government activities. Apart from designating 1982 as Information Technology Year, the British Government has launched a $1.2 million public awareness campaign. It is, moreover, in the process of initiating a variety of projects, including one designed to place a microcomputer in every secondary school by the end of 1982, and another-known as the Microelectronics in Education Program-that will provide instruction to teachers on the use of the computer as a classroom learning aid.

Clearly, the actions that nations are taking to encourage basic research and product-related R&D in information technology are in accordance with the ideas U.S. researchers have about Government support and participation. In hearings before the Subcommittee on Domestic and International Scientific Planning, Analysis, and Cooperation of the House Committee on Science and Technology, held in 1977, researchers from educational institutions and other nonprofit settings, as well as representatives from the computer hardware and software industry, advocated the establishment of large-scale, "critical mass projects" through which continued innovations in educational technology could be achieved. A number of participants cited the need for continuity in funding and ongoing support for projects lasting from 6 to 10 years rather than for the traditional 1- to 3-year cycles characteristic of Federal funding. They frequently mentioned the vital role that the Government plays in fostering development of the technology and in eliminating constraints that inhibit applications. William C. Norris, Chairman and Chief Executive Office of Control Data Corp., one of the U.S. firms most active in computer-based education, underlined the importance of the Federal Government's role in encouraging, through funding and other means, cooperative R&D efforts between universities and industry, in order to ensure that basic research is undertaken and new products continue to be developed and disseminated to specific markets. Recommendations made at the hearings also included the establishment of a national center and/or regional centers that would focus on further developments in educational technology .21

Implications of the Present Federal Role in Educational Technology R&D

Commitments made to R&D for educational technology at the level of fiscal year 1982 funding do not permit the Federal Government to continue to serve as a major participant in, and catalyst for, new research activities. Given decreased Federal funding levels and staff shortages, the degree to which the university community will participate in the future is also in question. Thus, private industry will have to provide the largest percentage of research dollars, and to perform most R&D functions. In a climate of increasing international competition, in which industry will tend to invest more in product-related R&D that ensures return on investment rather than in more fundamental research, the future of U.S.-based basic research and other nonmarket-oriented efforts is in doubt. This situation contrasts sharply with the European examples where na-

[21] Committee on Science snd Technology, U.S. House of Representatives, *Computers* hearing before the Subcommittee on International Scientific Planning, Analysis, and Cooperation, Oct. 4, 6, 12, 13, 18, and 27, 1977 (Washington, D. C.: U.S. Government Printing Office, 1978),

tional governments are becoming active participants in establishing national programs. In Third World countries, governments are also eager to utilize information technology to improve their training and educational programs.

Plans are underway at OE to establish an Educational Technology Initiative, a $16 million program that, over a 3-year period beginning in fiscal year 1983, will focus on the development of educational software. This initiative will also set up lighthouse school demonstrations, where applications of educational technology may be observed by school administrators and others, and an information clearinghouse and exchange.[22] By leveraging funds, the proposed program seeks to attract matching funds from industry to develop educational software to meet school specifications. Given past levels of Federal involvement in such public-private R&D projects, it is questionable whether the Federal contribution of $3.3 million extended over a 3- to 5-year period will be enough to stimulate private investments.

"Department of Education, Office of Educational Research and Improvement, *FY/83 Program/Budget Plan: Secretary Technology Initiative* (Washington, D. C.: Department of Education, February 1982).

Present and Future Support for Educational Technology R&D

Arguments favoring Federal involvement in R&D stress the riskiness of investment in these early stages of market development and the fact that much needs to be learned about how to use these new media most effectively. Some of the case studies that follow suggest that Federal support has been a critical factor in bringing experiments such as Sesame Street and PLATO to the point where commercial success stimulates private interest. If Congress decides to emphasize R&Din educational technology, several issues must be resolved.

- *Source of Funding.* —The Federal Government is only one of several potential sources of R&D support. Are there ways of providing Federal support that encourage investment in R&D by private industry, foundations, and even local and State education agencies? Mechanisms for coordinating and pooling research funds from multiple sources have to be explored.
- Level *of Funding.* —Several experts have expressed the opinion that current funding is far below the critical level necessary to make significant and rapid improvements in the state of the art. They point out that the French World Center has a starting budget of over $20 million per year and that previous Federal efforts in educational technology were funded at a significantly higher level than at present.
- *Stability of Support.* –Perhaps more important than the particular funding level is the fact that in order to encourage the formation of high-quality centers of research and to foster the entry of capable researchers into the field, there will need to be a long-term commitment to support R&D at whatever level is deemed appropriate.
- *Type of* Research .-There are four broad areas of research in learning technology: 1) research on the hardware technology itself to develop appropriate educational devices; 2) research on software development and courseware authoring techniques, such as how to make the best instructional use of information technology; 3) research on human-machine communication and interaction such as that on languages, keyboard and screen design, and the use of graphic images to transfer information; and 4) research on cognitive learning and on how individuals interact with educational systems.

- *Basic Research or Development* —The proper role of the Federal Government in funding research, however, is more clearly established in basic research and becomes less clearly so as the work is more developmental in nature. The closer a project moves to developing a potentially marketable application, the more these issues come into focus:
  - —what is the appropriate overlap between Government and private funding, and
  - —assuming that a Government funded project turns out to be a commercial success, how can it then best be moved quickly into the private sector?

Case Studies of Landmark R&D Dissemination Efforts in Educational Technology

This section includes four case studies of educational technology projects initiated partly or wholly with Federal funding. These projects have significantly affected the educational process, in some cases broadening the definition of what education is and where it can take place. The first case study describes the formation of the Children's Television Workshop; the second, the development, production, and marketing of PLATO, a computer-based learning system; the third, the establishment of the Computer Curriculum Corp. as an outgrowth of federally supported, university-based research in computer-based instructional systems for schools; and the fourth, the creation of CONDUIT, a nonprofit group that evaluates, packages, and distributes computer-based learning materials to secondary and postsecondary institutions.

Case Study 1: The Children's Television Workshop

The Children's Television Workshop (CTW), the creator of the prize-winning educational television series, Sesame Street and The Electric Company, was the first television program producer to design educational programs on a large scale specifically for preschool children. The CTW experience illustrates the highly successful use of technology for educational purposes, a substantial Federal Government investment and role, and the creation of a unique organization. It can therefore provide useful insights into and lessons about, the interrelation of public policy, technology, and education.

Context

CTW was formed in 1968 at a time when early childhood studies had established how important the preschool years are inlaying the foundation for subsequent intellectual development. It was a period when educators, increasingly aware of the exceedingly large number of hours that young children were watching TV each day, were becoming concerned about the kind of programing being offered. There was at the same time a growing sensitivity to the disparity in school readiness between advantaged and disadvantaged children.

CTW decided to experiment with a show that would attempt to capture the attention of young children, particularly those from low-income families. It was suspected that children from disadvantaged families watched TV even more than middle class children. Surveys showed that 90 percent of all families with incomes below $5,000 owned at least one television set and that disadvantaged families with preschool children had their sets on for an estimated 54 hours per week.

Budget and Organization

In 1968, CTW was setup as an autonomous unit within National Education Television, which served as a corporate umbrella for the purpose of receiving grants. Two years later, it became independent as a nonprofit corporation. The budget for its initial 2 years was $8 million-the first year for preparation, and the second for production and broadcast. The U.S. Office of Education agreed to pay 50 percent of this cost; the remainder was funded primarily by the Ford Foundation and the Carnegie Corp.

The present CTW budget is around $33 million, most of which is spent to pay the costs of its nonbroadcast enterprises such as the printing and postage for three widely circulated magazines.

Foundation support has tapered off, and Federal support for Sesame Street ended in fiscal year 1982. As a result, the staff was recently cut back, and CTW's community outreach program was reduced. While new programing continues for existing series, no new large-scale projects have been announced.

An effort has been made to generate new revenues through a whole series of products based on CTW programs. These include books, records, toys, games, and even clothing. CTW estimates that in 1982, royalty revenues from the sales of nonbroadcast materials will total $22 million, $16 million of which will go to cover costs, leaving an anticipated net revenue of $6 million to be applied to the continuing cost of Sesame Street and other educational projects.

CTW has also established a unique educational park known as "Sesame Place" in Bucks County, Pa. Designed for children age 3 and up, it is of special interest because, in addition to having dozens of outdoor play elements and indoor science exhibits, it provides 60 Apple computers on which children can plan educational games developed by CTW. A second park was opened in the summer of 1982 near Dallas, Tex. CTW also has a traveling roadshow called Sesame Street Live.

As another potentially important new revenue-producing venture, CTW is developing and marketing game software for the personal computer. While these games are intended to be educational, one of their design criterion is that they also be entertaining.

CTW Programs

CTW created three highly successful large-scale educational series for children: Sesame Street, The Electric Company, and 3-2-1 Contact. Sesame Street, the pioneer program, demonstrated that high-quality education programs could win mass audiences of children. After Sesame Street, CTW went on to develop another equally successful show in its reading program for young children called The Electric Company. Supplementary reading materials to reinforce both these programs were developed for students, teachers, and parents.

The most recent series, 3-2-1 Contact, was designed for children between the years of 8 and 12. Its aim was to acquaint children with the nature of scientific thinking and with some areas of scientific investigation. The initial season ran daily for 26 weeks. Five programs per week were built around a weekly theme such as light/dark, hot/cold, growth/decay, and fast/slow. As with Sesame Street and The Electric Company, actual production was preceded by careful study beginning with an examination of need. It was discovered, for example, that half of the States had no science requirements for teacher certification at the elementary school level, and that only 6 percent of 9-year-old students ranked science as their favorite subject. The developmental stages of 3-2-1 Contact involved 6 months for feasibility studies, 6 months for testing and development, and 6 months for production.

CTW also produced Feeling Good, an adult series on health; Best of Families, a series in American social history; and a commercial television family special: The Lion, the Witch, and the Wardrobe, which won an Emmy as the outstanding animated television special of the year.

CTW considers none of its program series to be a finished product. Programs are constantly brought up-to-date, expanded, and revised for greater audience appeal and educational impact. Sesame Street went on from its emphasis on cognitive learning to include such societal goals as cooperation, conflict resolution, and fair play. Sesame Street and The Electric Company programs were also adapted to the special needs of the mentally retarded, the deaf, and the Spanish speaking. 3-2-1 Contact was incorporated into museum programs throughout the country and was made an integral part of the Girl Scout program for obtaining a special 3-2-1 badge. 3-2-1 Contact has been used in prisons, and Sesame Street has been used with the refugee boat children.

Impact of CTW

With Sesame Street and The Electric Company, CTW proved that skillful educational programing could win a mass audience. Their combined audience in the United States has been estimated at 15 million people. They are the two most watched programs on public television. Sesame Street regularly commands a larger audience among 2 to 5 year olds than any other commercial television program. Studies conducted in low-income neighborhoods suggest that from 80 to 90 percent of the children watch. CTW programs are also cost effective. Cost per viewer per program, for each CTW program, has been less than 1 percent per day.

Teachers throughout the United States report that children arrive in school more knowledgeable and more able to master fundamental skills in reading and arithmetic. The CTW style has been copied by other television producers, and many parents and teachers have reported a change in their own thinking about education.

CTW programs are now offered in at least eight different languages and are shown in nearly 50 countries and territories. They have received 18 Emmy's, the European Prix Jeunesse, the Japan Prize, and numerous other awards and commendations. In 1979, the Smithsonian Institute's Museum of American History celebrated CTW's 10th birthday with a 3-month long exhibit.

Among the factors cited as contributing to CTW's success are:

- *Generous Funding.* –The large initial funding for Sesame Street was essential for achieving high quality.
- Planning.– Each project has been planned very carefully and in great detail, beginning with a feasibility study and working through all stages; from the time a CTW project was first considered to the time it is first broadcast typically takes 2 years.
- *Producer Freedom.* –CTW had complete control over the content and design of its program, and could make all programing decisions without outside interference.
- *A Delivery System Already in Place.*– Almost every household had a television set and the broadcast time and transmission facilities were available through the public broadcasting system.
- *Available Professional Expertise.*--*CTW* could draw from commercial television.
- *Personnel–The* project was initiated by highly competent, creative people.

Case Study 2: Development, Production, and Marketing of PLATO

PLATO, a computer-based education system designed for use with conventional and multimedia learning aids, was developed at the University of Illinois under the guidance of Donald Bitzer. Since its initiation in 1959, it has been supported by a combination of Federal, State, industrial, and private agencies and organizations. Most of the financial assistance was provided by NSF with some funding from OE. When OE discontinued its support, several corporations also withdrew theirs. Control Data Corp. (CDC) was eventually licensed by the University of Illinois to produce and market the PLATO system.

CDC is a worldwide computer and financial services company based in Minneapolis, Minn., employing 60,000 people and marketing products and services in over 47 countries. In 1981, CDC's net earnings totaled $171 million on combined revenues of $4.2 billion. Since 1962, the company has invested more than $900 million in its educational products and services.

CDC maintains that, in addition to its other profitmaking activities, it can also make a profit by addressing itself to the most intransigent problems of our society. In cooperation with business, educational, and religious organizations and government agencies, CDC has developed projects relating to the inner city, low achieving students, prison inmates, small businesses, and independent farmers. Some projects are entirely devoted to education and some are only partially so. The PLATO learning is heavily used in many of these efforts.

PLATO Computer-Based Education

In 1981, there were 18 PLATO systems, 10 owned and operated by CDC and 8 by universities. Nine of the eighteen are located in the United States and Canada, and nine are overseas. The cumulative number of terminal contact hours on PLATO IV passed the 10 million mark in 1979. This is by far the most extensively used system of computer-based instruction in the world.

A PLATO system consists of one large central computer that connects to many terminals by long-distance telephone lines or satellite. There is no technological limit to how far a terminal might be from the main computer; hundreds of miles is not uncommon. At the terminals, individuals or small groups of students can have access to a wide range of instructional materials, which include presentations, drills, tutorials, dialogs, simulations, problem-solving, and games.

PLATO learning can also be delivered on microcomputers using disks that store the learning materials. In 1981, CDC announced its own microcomputer, the Control Data 110, which runs PLATO as an application. The 110 also serves as a small business computer and can be hooked up to the central PLATO system to deliver PLATO learning on-line.

The nature of the conversation or interaction between a student and the computer depends on the way in which the author has written the instructional materials. Generally, the interaction has these characteristics:

- The student gets immediate response from the computer whenever the student asks or answers a question.
- The computer adjusts its lesson to meet the particular needs and abilities of the individual student at that moment.
- The computer keeps track of what the student has already learned.
- The student can work in private without fear of exposing his weakness to other people.
- The student can use the computer to assist him in visualizing ideas through graphics, computations, examples, and simulations.

In addition to interacting with the computer program, the student can use the PLATO network to discuss his studies with teachers or other students, even though they may be physically located thousands of miles away. The computer can diagnose, evaluate, teach, test, and keep records. The terminal screen is tactile-sensitive. If a child is learning to read and does not know a word–e.g., "mouse" -he can touch the word and, as the word mouse is spoken, it will be replaced by a picture of a mouse.

Availability and Use of PLATO

In 1981, about 6,000 PLATO terminals were used in diverse settings. One type of setting was the CDC Learning Center, which is open to the general public and which offers courses from a third grade level to advanced postgraduate work. There are 115 CDC Learning Centers throughout the United States, the subjects taught at these centers include business, industry, and computer-related subjects as well as foreign languages, English, math, sciences, education, psychology, the arts, and career counseling. Learning centers offer business, industry, government agencies, and schools a cost-effective alternative to traditional training programs. A company or agency can have PLATO programs written or adapted to their particular training needs and have the programs made available to their employees throughout the country.

Customers can install terminals that deliver PLATO CBE, either on-line or off-line, on their own sites. Schools have terminals onsite in all cases. With the release of PLATO courseware to other micros, however, the use of PLATO learning will be able to increase greatly at a highly reduced cost.

Industry

To date, the primary use of PLATO has been for inservice training in industry. Courses include basic management training, accounting, economics, equipment operation and maintenance, powerplant operation, computer fundamentals, and computer programing.

Examples of training needs to which PLATO has been adapted include:

- United Airlines uses PLATO to bring 367 new trainees each year up to entry level for transitional training. The PLATO-assisted program takes 11 days compared to the 15 days formerly required without PLATO. United Airlines estimates that it saves $29,827 per year by using the PLATO systems.
- Control Data Institutes train 7,000 programmers, operators, and technicians yearly for the computer industry. In the United States, 60,000 people have received this training since the first Control Data Institute started in 1965. More than 50 percent of the training is on PLATO.
- The Navy successfully adapted CDC's Basic Skills Learning System to train recruits at the Navy Recruit Training Center in Orlando, Fla. With the help of PLATO, two to three times the usual number of recruits were trained by the same-sized staff, and they completed their required course work in fewer hours. This PLATO program was administered by regular noncollege Navy personnel after only 2 weeks of specialized training.

Higher Education

Many colleges and universities use PLATO CBE. Some examples of the different ways in which PLATO has been integrated into educational curricula are:

- The University of Colorado uses PLATO for developmental English, physics, electrical engineering, accounting, educational psychology, and astronomy.
- The Reading Pennsylvania Area Community College offers PLATO courses in basic skills, training for local industry, and enrichment programs in math, Russian, and other subjects for exceptionally advanced high school students.
- The University of Delaware uses PLATO in its School of Music to provide drill and practice with musical notes played by a synthesizer connected to the terminal and offers PLATO courses in dressmaking, nursing, and agriculture.
- The American College offers courses in life insurance and related financial sciences to students in all 50 States and 12 foreign countries. The networking power of PLATO is ideal for this widely dispersed student body.
- The University of Quebec has eight terminals in almost continual operation on the Trois-Rivieres campus. Faculty members create their own lessons in French, chemistry, English, physics, geometrical optics, data processing, and psychology. It sometimes takes as long as 250 hours to produce a 60-minute lesson.

Public Schools

Although CDC is interested in introducing PLATO into public elementary and secondary institutions, PLATO has not been utilized by public schools primarily because of its cost. However, with PLATO learning new being delivered on micros-both on CDC microcomputers and those of other companies-costs may drop substantially. One example of a successful application of PLATO is in an inner-city school in Baltimore. In 1979, 200 of Walbrook High School's 538 seniors failed the City of Baltimore math and reading proficiency tests. After 60 days of using PLATO, all but nine passed the test. PLATO has helped Walbrook's low achieving students to increase their academic levels as many as three grades in 1 year.

Today, 180 Walbrook students each receive 25 minutes of PLATO instruction daily on one of the school's 12 terminals. At midterm, a second group of 180 students is chosen. Thus in 1 school year, 360 of the school's 2,350 students will have received PLATO-assisted instruction. In addition, two junior high schools have two terminals each, and six elementary schools have one terminal each. The Baltimore PLATO project, initially subsidized by CDC, is now funded by the Baltimore City School System.

Special Populations

American Indians.–The American Indian Project of St. Paul, Minn., used the PLATO Basic Skills Program to meet the remedial educational needs of 1,200 American Indian students in 65 urban areas. Some students were able to raise their academic levels by 5 years in only 6 months of work.

Home Workers.–PLAT0 is used to train and provide employment for homebound, disabled employees. CDC has created jobs in programing for businesses and in developing courses for the PLATO system. The computer network makes communication possible between employers, employees, and fellow workers, thus establishing a community that can give peer support to homeworkers nationwide.

Prisoners. --In 1974, CDC chose correctional institutions as one entry point for its Basic Skills Learning System. A pilot PLATO Basic Skills Learning program was installed in the Minnesota State Prison in Stillwater. After only 7 hours of PLATO study, inmates averaged gains of 1.6 grades in reading; after 12 hours, they averaged gains of 2.16 grades in math. Students were anxious to use the computer, and here again, as in the case of the Indian program, academic success was matched by improved social attitudes. PLATO is now used in 29 correctional institutions located in 10 States and in the United Kingdom.

Unemployed.– A CDC program specifically designed for the hardcore unemployed, called Fair Break, consists of the PLATO Basic Skills courses in math, reading, and language, as well as a course in how to choose and get a job. The coursework is supplemented by a counseling and referral program that helps adult students cope with problems relating to health, finances, drugs, and interpersonal problems. The program also involves peer-group counseling. CDC provides part-time work to program participants for the duration of the course.

Assessing Benefits and Cost Effectiveness of PLATO

In attempting to assess the benefits or cost effectiveness of a given PLATO application, three factors must be taken into account: the delivery system, the implementation, and the courseware.

PLATO as a Delivery System.—While some evaluative reports criticize minor aspects of the central delivery system, most regard the central delivery of PLATO learning as being exceptional, and believe that its full potential is still unrealized. The major criticism of PLATO as a delivery system has been its cost. The most clear-cut beneficial or cost-effective uses of PLATO are those in which:

- Educational opportunities are delivered that would otherwise be unavailable to the learner population in question.
- Instruction is brought to learners who would otherwise have to be transported to a distant site for training.
- Needed skills and knowledge can be acquired more quickly through a PLATO course than they can through an alternative instructional method.

Implementation of PLATO. --Implementation refers to the setting and manner in which instruction is taken-the institution, the learner population, the role and personality of the teacher, the relationship of the PLATO learning experience to other instructional components, the motivational aspects of the environment, and so forth. In a study conducted by the Educational Testing Service, the use of PLATO in four community colleges was found to have no significant effect on student attrition, student achievement, or student attitudes toward their academic experience. Participating instructors tended to view PLATO favorably, but teachers judged their PLATO students less favorably than their non-PLATO students in ability, motivation, and achievement.

Implementation in Military Training Settings.—The cost effectiveness of computer-based instruction in military training has been investigated by analyzing 30 studies of computer-based instruction, seven of which used PLATO; the rest of which used all other computer-based systems. It was concluded that, on the whole, computer-based instruction reduced the time normally needed by students to complete courses using conventional instruction by 30 percent. The difference in the amount of time saved by individualized self-paced instruction compared with computer-based instruction was found to be relatively small. The PLATO system was not found to be more effective than other computer-based systems' studies. Furthermore, according to two cost-effectiveness evaluations, the Army PLATO IV system was judged to be less effective than individualized (noncomputerized) instruction.

Implementation in College Settings.–A comprehensive analysis of computer-based college teaching was made that included 59 studies of which an unspecified number were of PLATO courses. Although about 20 different characteristics of these courses were analyzed, they were not classified according to the particular delivery system that was used (e.g., PLATO, TICCT). It was found that a typical computer-based institution class raised student achievement by about one-quarter of a standard deviation unit.

Courseware.--The term courseware refers to the programs on PLATO that contain both the content and logic of the instruction. An extensive variety of different kinds of courseware have been developed for this system.

Seven evaluation studies of the PLATO Basic Skills Learning System have indicated that the curriculum is at least as effective as some conventional methods in providing remedial instruction in math and reading. In one such study, 236 high school students in Florida received remedial instruction in mathematics via PLATO. The median gain for all students was 1.5 grade equivalents after they have spent an average of almost 20 hours in the math lessons. This equivalent equates to about 1.0 grade equivalent gain for 13 hours in the curriculum.

Because there was no control group in the Florida study or in several of the other evaluations of the basic skills curriculum there is no way of knowing whether other instructional methods might have been as effective or as cost effective. Where control groups were included in basic skills evaluations, the results have been mixed or inconclusive.

Students using PLATO Basic Skills courseware tend to cover subject matter more quickly than do control groups. For example, at a Minnesota correctional facility, 20 reading students gained an average of 1.02 points in test scores after 9.6 hours of PLATO-assisted instruction. The control group of 6 students that had 15 hours of instruction gained 0.08 points. Twenty math students gained 1.75 points after 17.6 hours of PLATO. After 25 hours of non-PLATO instruction the corresponding 6 control students gained an average of only 0.35 points. In a comparison of 15 PLATO students with 15 controls at Bexar Detention Center, the PLATO students gained 1.13 points in math tests. The control group, after more than twice the amount of instruction time, gained only 0.19 points.

PLATO and other computer-based instruction methods have capabilities that provide unique learning experiences that are impossible or impractical using other means. One example is a cardiology course at the University of Alberta, Edmonton, Canada. These programs can simulate virtually any heartbeat. The student is aided by a "stethophone," an electronic stethoscope that amplifies the low-frequency sounds of the heart, and a terminal screen that displays a diagram of the patient's body. The student can hear heart sounds indicative of virtually all coronary conditions, providing an experience which traditionally would have required first visiting the radiology department to review X-rays, and then the wards to see the patient. Because of the wide variety of cardiac dysfunctions, the urgent nature of cardiac lesions, and the large number of medical students, students normally would not have the opportunity while in medical schools to observe every kind of heart disease. Previously, classes as large as 118 students would spend 50 hours in a traditional lecture environment. With the PLATO system, that instructional time has been reduced to an average of 20 hours and with a higher learning rate.

Case Study 3: Computer Curriculum Corp.

Computer Curriculum Corp. (CCC) is a for-profit company that develops and markets computer-assisted instruction (CAI) systems to schools. It was founded in 1967 by Patrick Suppes as a marketing outgrowth of R&D in CAI that began in 1963, at the Institute for Mathematical Studies in the Social Sciences at Stanford University. The institute's first instructional program was a tutorial curriculum in elementary mathematical logic. A preliminary version of its elementary mathematics program was tested in 1964. The first use of CAI in an elementary school took place in 1965, when fourth-grade children were given daily arithmetic drill-and-practice lessons in their classroom on a teletype machine connected by telephone lines to the institute computer. (Before that, the children were transported to the campus.)

During this time, the institute engaged in R&D on the use of CAI in teaching reading. In 1964, this effort was developed into the Stanford Initial Reading Project, the purpose of which was to provide a comprehensive, individualized curriculum that would improve basic reading skills. First, however, the project analyzed the obstacles encountered by culturally disadvantaged children in acquiring reading skills.

CCC Product Development

With private financing, CCC began developing a marketable CAI package based on the research that had been done at Stanford. By about 1973 the hardware became inexpensive enough to develop a system that could be marketed at a reasonable cost. Thus, CCC started as a marketing organization in about 1974. At that time, about 20 schools throughout the country were using CCC's curricula. During the 1970's, CCC had the only commercially viable and extensively validated computer-based curriculum for elementary schools.

CCC Products and Services

The CCC staff–about 200 employees—provides a turnkey system that includes computer hardware, software, curriculum, and support services (e.g., teacher training and equipment maintenance). A typical system in a school has about 16 terminals in a CAI laboratory, although this amount varies per school.

The curricula consist of drill-and-practice courses that supplement regular instruction in basic skills, primarily in reading and mathematics. In each course, students use the drills for 10 minutes per day. The three most widely used curricula are the mathematics strands, grades 1-6; reading, grades 3-6; and language arts, grades 3-6. Newer courses, such as reading for comprehension and problem solving, are rapidly being adopted.

Funding for R&D

Initial support for the work in elementary mathematics and reading came from a private foundation and was followed up by support from NSF and OE. Since 1963, NSF has supported work with elementary school gifted children and OE funded the reading project at $920,000 from 1964-67. From 1966-68 OE supported related work in CAI at Stanford. Work with disadvantaged students was supported by title III of the Elementary and Secondary Education Act of 1965, and work with the handicapped, especially deaf students, was funded by the Bureau of Education for the Handicapped from 1970 to 1973.

A reoriented project in elementary reading and math was conducted from 1967 to 1970 with a grant from NSF. Its aim was to design and implement a low-cost CAI curriculum that would act as a supplement to classroom instruction. Because the institute lost its Federal R&D support in elementary and secondary curriculum development after 1970, it had to reuse the elementary school curricula, making some special applications for hearing-impaired students. The institute then turned most of its attention to the development of university-level curricula.

Impacts

Nearly 1 million students have used CCC curricula over the past 10 years. In the 1981-82 school year, about 200,000 students from 30 States, most of whom are from disadvantaged homes in inner-city and rural environments, used them on a daily basis. CCC educational materials are paid for with title I and other Federal categorical aid.

Evaluation Studies

CCC curricula have been extensively evaluated by many groups, including individual school systems. A wide variety of populations were studied including inner-city students; students in different sections of the country; rural students in Appalachia; American Indian students in New Mexico; and bilingual, deaf, and mentally retarded students.

The studies have shown that, when used as recommended, CCC's elementary CAI curricula are effective in increasing student achievement levels. Studies comparing gains of CAI students with gains of non-CAI students show that the curricula serves as an effective form of supplementary instruction. Studies comparing CAI programs with other supplementary programs suggest that CAI participants are more likely to meet achievement objectives. Longitudinal data indicate that achievement levels can be expected to increase steadily over several years of CAI participation and that over summer holidays students do not seem to forget the concepts reviewed.

The studies also showed that several benefits can be associated with the use of CCC curricula. First, because of the categorical aid provided by the Federal programs, CAI was introduced on a broad scale among disadvantaged students, including those that come from low-income backgrounds, that are members of minority groups, or that are handicapped. Traditionally, innovation takes place in affluent schools. Second, through the detailed and highly individualized feedback provided by the computer, students acquire habits of precision in their work. Third, increased student motivation and decreases in vandalism and truancy were reported. Finally, students learned basic skills in reading and math.

Evaluations led to the following findings:

- Federally supported R&D had a major impact on the state of the art in computer-based learning and teaching. Support from OE and NSF R&D at Stanford University significantly influenced the development of curricula and methods of computer-based learning.
- The focus of the Elementary Secondary Education Act on the disadvantaged resulted in the development and implementation of high-technology systems that are effective in providing such students with basic skills.
- Numerous evaluations of the use of CCC curricula by a wide variety of students have all clearly demonstrated that, when used as recommended, they are effective in increasing achievement levels in basic skills.

Case Study 4: CONDUIT

CONDUIT is a 10-year-old nonprofit organization that packages and distributes high-quality computer-based instructional materials to colleges, universities, and secondary schools. In 1971, when CONDUIT was conceived, the major barrier to instructional computing was a lack of quality learning materials and computer software. Although materials had been developed at universities and colleges, they were being used only at the originating institution. No organization existed to distribute instructional programs. Because there were so few programs available, there was no visible market large enough to justify investment by commercial publishers. Without distribution mechanisms or author incentives, few high-quality materials suitable for distribution were being developed.

Established as a partial solution to this problem, CONDUIT was intended to provide the organizational link that would search for materials, test and review them, revise them so that they could be used at different institutions or on different computers, and distribute these packages to other institutions.

Profile of CONDUIT Today

CONDUIT has received support from NSF and the Fund for Improvement of Post Secondary Education (FIPSE). It distributes NSF educational materials that are reviewed, well documented, programed for ease of transfer to different computers, and kept up-to-date. The instructional materials are all reviewed by experts in each subject area for conceptual validity, instructional usefulness, and overall quality.

A typical institutional package consists of a computer program written in BASIC or Fortran, a student guide explaining objectives and methods of its use, an instructor guide illustrating course applications, notes explaining how to install the program on the computer, and the programs written in a form that can be read by the computer. Programs are provided both for use on small personal computers and for use on the large timesharing computers typically found on university campuses.

As of August 1981, CONDUIT distributed about 100 different packages for use in college and precollege courses in biology, chemistry, economics, education, geography, humanities, management science, mathematics, physics, political science, psychology, sociology, and statistics. CONDUIT has gained an international reputation, distributing nearly 9,000 packages to 1,500 institutions in all 50 States and 12 foreign countries.

Budget and Financing

CONDUIT currently operates on a monthly budget of about $30,000. Two-thirds of this amount is derived from revenues from the sale of packages and other publications. One-third, or about $10,000, is provided from grants from NSF's Office of Science and Engineering Education Directorate and FIPSE. Since its inception in 1971, CONDUIT has received about 2.5 million of support from NSF.

Benefits

The direct beneficiaries of CONDUIT operations include students, teachers, and authors; commercial publishers; and other groups benefit indirectly.

- About 1 million students have benefited from using CONDUIT materials, based on conservative estimate of 120 student users per package. (At a large university, one package might be used by hundreds of students over several years.)
- At least 18,000 teachers have benefited from the availability of CONDUIT materials, at an average of two teachers per package. Because CONDUIT materials are so well documented, teachers may readily tailor the materials to fit their own course and teaching style.
- Authors of computer-based learning materials also benefit from CONDUIT. Over 2,000 copies of CONDUITS guidelines for authors

have been distributed and over 100 have had their materials packaged. Authors are rewarded by having their materials widely used, and they receive royalties on sales.

- Commercial publishers are also indirect beneficiaries. Now that the commercial viability of instructional computer materials has been demonstrated, commercial publishers have become more interested in marketing such materials.
- CONDUIT serves as a useful model to other groups both within the United States and in other countries. The Northwest Regional Education Laboratory drew on CONDUIT expertise in establishing MicroSift to evaluate educational software for precollege applications. The British have drawn heavily on the CONDUIT model in establishing a similar network.

Findings

- *Sustained Support.* –CONDUIT received sustained support at somewhat below half a million dollars per year, from NSF for several years before there was any significant payoff.
- *About* 40 *percent of CONDUIT packages were originally developed under Federal grants.* Thus, it has provided an important dissemination function for curriculum development work.
- *It is possible for the Federal Government to make a major contribution to improving education through a minimal dollar investment, by the creation of an appropriate organizational entity.* By 1972, numerous studies had concluded that no existing organization could perform the functions necessary to break the cycle of barriers to development and dissemination of educational computing materials. A new kind of organization would be needed. Many difficulties were encountered in attempting to establish such a new organization. A few key individuals in academia and NSF were committed to the idea, however, and it was through their sustained efforts that the organization finally became a viable entity. CONDUIT's relatively low level of Federal support, and thus low visibility for several years, was probably an advantage in working out the numerous technical, political, and educational problems involved.
- CONDUIT could not have become a viable organization had it not been able to use the revenues from the sale of packages for its continued operations. This posed many legal and contractual difficulties for NSF. However, after prolonged negotiations, financial arrangements were made that enabled CONDUIT to become close to self-sustaining.
- *Coordination With Other Programs and Projects.* —The NSF Science Education Directorate encouraged projects supported by its other program areas to collaborate with CONDUIT. This collaboration provided important links to developers of exemplary materials and also provided the development projects with guidance on how to make useful products.
- *The support of established institutions, while* essential initially, has become less important over time. CONDUIT was originally established as a consortium of major educational computing networks and university computer centers. These institutions and networks provided the testing ground and data base for the early CONDUIT investigations into the area of sharing and transporting educational software.
- It is possible to increase the supply of high-quality, marketable materials by conveying appropriate guidelines and standards to authors and developers. CONDUIT has found that as more authors and development projects use its guides, the amount of quality materials available for distribution has increased.
- From 3 to 4 years are needed in order to realize a return on investment for quality computer-based instructional materials.

This figure may be shortened somewhat as the number of computers increases. However the present situation is such that the time period required for return on investment is too long for most commercial publishers.

In creating and demonstrating the market for high-technology materials, quality of products is more critical than quantity.