INNOVATIVE EDUCATIONAL PROGRAMS OF COLORADO STATE UNIVERSITY

A

Status Report

On

N.S.F. Education Directorate Sponsored Programs

by

C.S.U. Principal Investigators

Colorado State University
Fort Collins, Colorado 80521

Special Report to the Advisory Committee for Science Education

of the National Science Foundation

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SUMMARY

For the past six years, Colorado State University has provided complete graduate study programs for engineers employed in Colorado's industrial and government facilities. Under the SURGE program, regular campus classes add part-time students who participate by seeing the classes on video tape on a two-day delayed schedule at their place of employment. The faculty maintain consultation hours by telephone and visit the industrial sections twice a quarter. The video taping technique has been extended to provide educational programs for the students and teachers of community colleges and high schools, and also inmates of the state penitentiary. An average of 31 courses per quarter were offered in 1972-73 to 34 off-campus locations and 27 student groups. Over 400 video tapes were delivered by Colorado State University each week of the academic year.

Faculty productivity has been increased significantly under the SURGE program. The operational costs and capital outlay for these programs are summarized herein. The average cost of instruction is shown to be appreciably lower than the cost for traditional instruction on campus.

Resource sharing by Colorado State University with Colorado community colleges under the CO-TIE program includes a wide range of activities. A state-wide computer network is now operational supported by faculty workshops on the integration of the computer into college curricula. BIOCO-TIE focuses the talent of the biology faculties of two universities and thirteen community colleges in the production of color videotapes and other audiovisual materials to support effective audio-tutorial techniques in biology instruction.

The Computer Managed Learning Laboratory is currently conducting an evaluation of a unique multi-media learning system. Some of the features, experience and potential of this system are outlined herein.

INTRODUCTION

This paper summarizes the current status of several innovative education programs which have been partially supported by grants from the Education Directorate of the National Science Foundation.

The SURGE program in its first year was partially supported by the National Science Foundation, Division of Graduate Education in Science, Grant GZ-753 (L. V. Baldwin, Principal Investigator). CO-TIE received partial funding from National Science Foundation, Division of Undergraduate Education in Science, Grant GY-5305 (Lee M. Maxwell, Project Director). Federal participation in the computer network and related teacher-training and curricula development came from National Science Foundation, Office of Computing Activities (now the Computer Innovation in Education Section), Grant GJ-1086 (Lee M. Maxwell, Project Director). The CO-TIE computer project is also being partially funded by grants from Control Data Corporation. Partial support for the engineering laboratory development project was awarded by NSF Grant GY-8197 (L. M. Maxwell, Project Director). BIOCO-TIE is partially supported by National Science Foundation, Division of Undergraduate Education in Science, Grant GY-9337 (John P. Jordan, Project Director). Ralph Niemann directs the in-service teacher training activities of the Department of Mathematics, College Science Improvement Program, GY-6599, and In-service Seminar Program, GY-5424. The Computer Managed Learning Laboratory was initially funded by the Control Data Corporation, but its current activity is funded by N.S.F., Computer Innovation in Education Section, GJ-30613 (Sept., 1971) and EC-30613 (May 1973) under the direction of Robert W. Hayman and William Lord.

UNIVERSITY-INDUSTRY COOPERATION: COLORADO SURGE*

Colorado has a concentration of technologically based industries and government facilities situated along the eastern slope of the

*Colorado State University Resources for Graduate Education

Rocky Mountains in a narrow, 130-mile strip extending from Fort Collins to Pueblo (see Figure 1). In order to provide continuing educational opportunities for the professional employees of these industries, the College of Engineering of Colorado State University initiated Project Colorado SURGE in 1967. The principle aim of SURGE is to provide graduate-level course work to professional employees of Colorado industry and government agencies regardless of geographical situation. Complete Master of Science degree programs are provided in Civil, Electrical, Mechanical and Industrial Engineering. Numerous courses are offered by the Departments of Mathematics, Statistics, Atmospheric Science, Psychology, Physics, Watershed Science and the College of Business (ref. 1). An expanded program under SURGE leading to a Master's degree in Business Administration was announced by the College of Business in 1972-73.

The course work is delivered to industries in the form of videotaped class sessions with supporting written materials, produced for classes on the CSU campus. Every course in this program is a regularly scheduled offering on campus attended by full-time students. The SURGE classes are held in specially equipped studio-classrooms so that not only the lectures but also the student questions and discussions are recorded on video tape. After the tapes are made, they are packaged with class materials, assignments and examinations, and carried by a commercial delivery service to each of the industrial and government locations. The class sessions are viewed on a regularly scheduled basis by the off-campus students. The off-campus classes usually view class presentations two days following the on-campus class; over 80 per cent of these off-campus sessions are during regular working hours. Tapes, however, may be retained by the industry so that any person missing a class session may see the tape at some later time. After being viewed at the off-campus location, the tapes are returned to the campus, erased, then reused to record other class sessions.

The SURGE students are required to complete the same assignments, reports and examinations as the on-campus students. Laboratory work

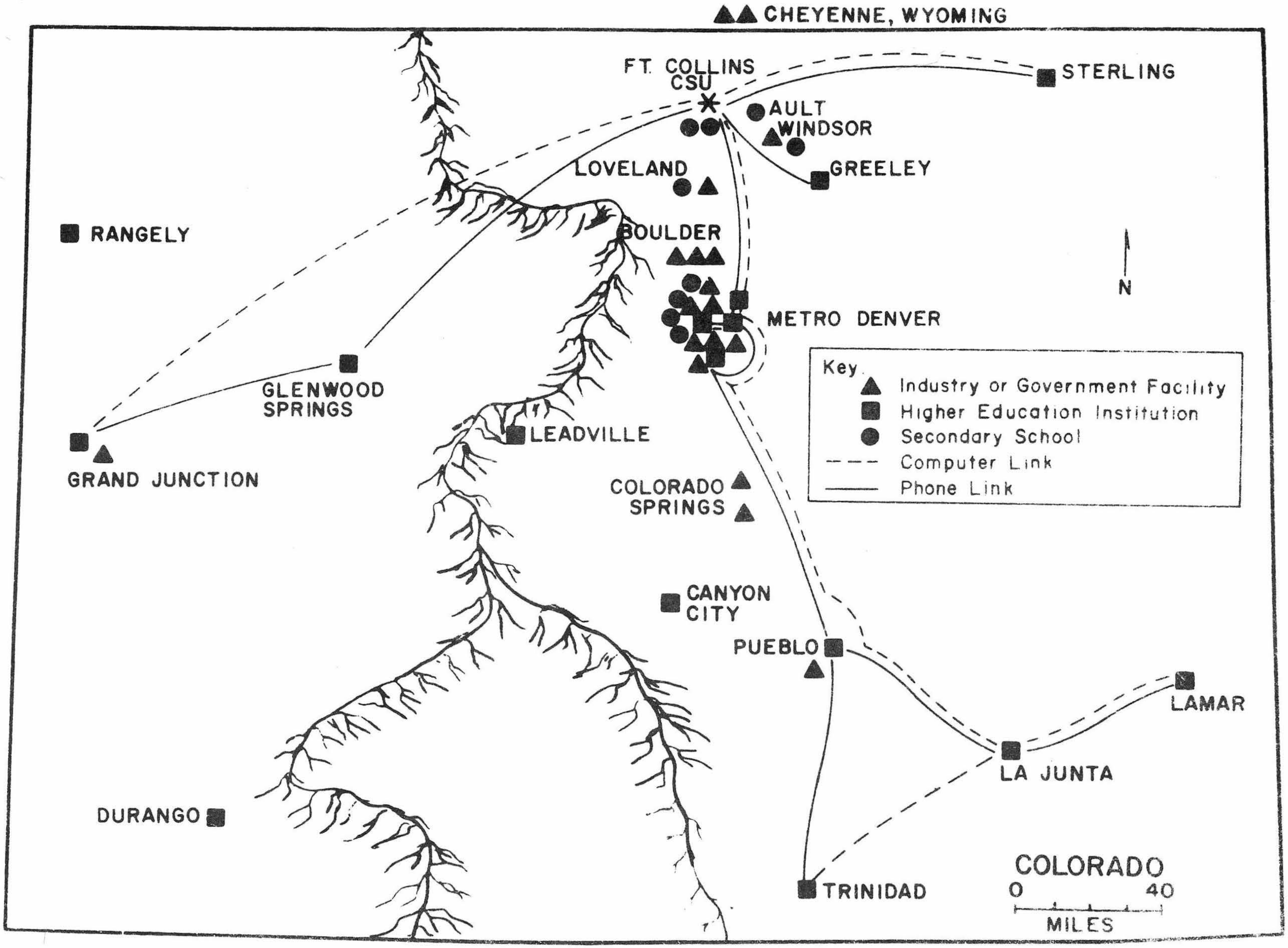

FIGURE I:
LOCATIONS OF INNOVATIVE, OFF-CAMPUS EDUCATIONAL PROGRAMS OF COLORADO STATE UNIVERSITY

is frequently required in electrical engineering courses; the SURGE students use the laboratory facilities of their employer to perform these studies. The students of many courses need computer facilities to complete assignments. Here again, the industrial computer facilities are utilized. To minimize the inconvenience of limited library facilities, the faculty frequently send a single Xerox copy of reference articles to each off-campus section.

In the spring of 1973, 34 industrial and government facilities participated in the SURGE program. These are listed in Table 1.

Table II is a summary of the number of courses and locations, and student enrollments, both on-campus and off-campus, for the history of the program. Appendix A lists the course tities and off-campus enrollments during this six-year period.

During the first three years of SURGE, the CSU Human Factors Research Laboratory conducted an educational evaluation of the program (ref. 2). These studies consistently indicated that the students in the remote classes were attaining levels of achievement equal to that of the on-campus students. Later surveys showed off-campus students' attitudes toward the video tape method of instruction were more favorable than to other options available to them. The faculty and on-campus students generally have favorable attitudes as well.

Students in the SURGE program are enrolled as graduate students of CSU and are charged the regular resident, part-time tuition rate which is currently $23 per quarter hour. The participating industries and government agencies provide playback equipment, classroom facilities and administrative support of the program. No other charge is made by the university. The SURGE students receive academic credit on official CSU transcripts. No notation is made to distinguish on-campus and off-campus students in the records.

TABLE I

INDUSTRIAL FIRMS AND AGENCIES

PARTICIPATING IN SURGE PROGRAM

Academic Year 1972-73

Company or Agency	
Adolph Coors Brewery	Golden, Colorado
*Ball Brothers Corporation	Boulder, Colorado
Bell Telephone Laboratories	Denver, Colorado
Canal Zone Society of Professional Engineers	Balboa Heights, Canal Zone
C. F. & I. Steel Corporation	Pueblo, Colorado
Cobe Laboratories	Lakewood, Colorado
Colorado Department of Health	Denver, Colorado
Colorado State Penitentiary	Canon City, Colorado
*Dow Chemical Company	Golden, Colorado
Eastman Kodak Company	Windsor, Colorado
First National Bank of Denver	Denver, Colorado
Hewlett-Packard Company	Colorado Springs, Colorado
*Hewlett-Packard Company	Loveland, Colorado
*Honeywell, Inc., Test Instrument Division	Denver, Colorado
*I. B. M. Corporation	Boulder, Colorado
Lamar Community College	Lamar, Colorado
Lowry Air Force Base	Denver, Colorado
Marathon Oil Company	Littleton, Colorado
*Martin-Marietta Corporation	Denver, Colorado
Mesa College	Grand Junction, Colorado
M & I Incorporated	Fort Collins, Colorado
Mountain States Bell Telephone	Denver, Colorado
*National Center for Atmospheric Research	Boulder, Colorado
Nelson, Haley, Patterson & Quirk Inc.	Greeley, Colorado
Northeastern Junior College	Sterling, Colorado
Stearns-Roger Company	Denver, Colorado
U. S. Air Force Academy	Colorado Springs, Colorado
U. S. Bureau of Reclamation	Denver, Colorado
U. S. Bureau of Reclamation	Billings, Montana
U. S. Geological Survey	Denver, Colorado
U. S. Geological Survey	Cheyenne, Wyoming
White Sands Missile Range	White Sands Missile Range, New Mexic
Woodward Governor	Fort Collins, Colorado
Wyoming Highway Department	Cheyenne, Wyoming

* Original locations for initiation of program, Fall 1967.

TABLE II

COLORADO STATE UNIVERSITY

SURGE ENROLLMENT SUMMARY

1967 - 1973

Quarter		Number of Courses	Number of Locations	Number of Students On-campus	Number of Students Off-campus	Total/Yr. Off-campus
Fall,	1967	4	7	105	189	
Winter,	1967	9	9	132	249	
Spring,	1968	8	9	100	206	644
Fall,	1968	12	13	283	341	
Winter,	1969	15	14	305	320	
Spring,	1969	13	15	314	288	949
Fall,	1969	15	14	209	336	
Winter,	1970	14	14	262	295	
Spring,	1970	14	14	162	165	796
Fall,	1970	17	15	232	403	
Winter,	1971	20	19	289	316	
Spring,	1971	18	16	235	202	
Summer,	1971	6	6	67	51	972
Fall,	1971	22	23	410	351	
Winter,	1972	24	22	353	284	
Spring,	1972	23	20	331	253	
Summer,	1972	7	10	79	93	976
Fall,	1972	32	24	527	426	
Winter,	1973	30	28	750	426	
Spring,	1973	31	29	367	275	
Summer,	1973	17	16	96	150	1,277

While there is no prescribed pattern, each faculty member teaching on SURGE is encouraged to make at least two visits per quarter to each industrial location for direct contact with each of his students in a class. Additional live interaction between faculty and students occurs in occasional telephone calls and more rarely, by student visits to the CSU campus.

In addition to courses being sent to the Colorado locations, CSU is currently offering courses to selected locations in California, New Mexico, Montana, South Dakota and Wyoming on an experimental basis.

Advantages realized in the video taping of upper division and graduate courses for engineers and scientists in SURGE are (ref. 3):

1. Video tape allows complete freedom of scheduling of courses at each industrial location on a two-day delayed, regular sequence.
2. Video tapes may be retained for those individuals who would otherwise miss a class because of illness or travel.
3. Students both off-campus as well as on-campus may use the tapes to review lectures.
4. Courses may be taught at locations beyond the bounds of a feasible live ITV system (there is no ITV system operating in Colorado at this time).
5. The capital cost of the video taping operation is significantly less than a live TV system capable of providing the same opportunities.
6. Faculty may review classroom presentations for self-evaluation.

During the first six years of the SURGE program, there have been 50 engineers of participating companies who have been awarded M.S. degrees completely through the video tape program. Over 16,000 quarter hours of university credit have been earned by other professionals without leaving their place of employment. The program operates at a reasonable marginal cost to regular campus offerings as is discussed in detail in Appendix B.

UNIVERSITY-COMMUNITY COLLEGE AND COLLEGE COOPERATION: CO-TIE*

In the fall of 1968, Colorado State University and six other Colorado colleges, five two-year institutions and one four-year college, initiated a program which was originally aimed at enhancing the pre-professional course offerings at the six colleges. Project CO-TIE began with video taping sophomore level engineering courses at CSU and presenting them to students at the six participating colleges, thereby making it easier for the students to transfer between these colleges and the engineering programs of universities (ref. 4 and 5). This cooperative program has now expanded to more colleges and into a variety of resource sharing activities which are summarized in Figure 2.

Much of the CO-TIE program activity utilizes the same equipment, studio classrooms, recording area and distribution methods as the SURGE program. In addition to the video taping equipment, CO-TIE employs a statewide audio network which interconnects the campuses and enables a continuing dialogue to occur between the faculty and students involved in the program. Using the audio network, CSU instructors provide real-time recitation periods to the students at the participating colleges. Instructors employ blackboard-by-wire equipment to illustrate subject matter for the off-campus students. Slow-scan television has also been used to transmit video frames over this network to the off-campus students during recitation periods.

By offering these college students courses identical to those taught at CSU, CO-TIE strives to overcome the age-old problem of subject matter deficiency which faces many students who transfer to the university. CO-TIE courses have saved many students at least a year in achieving their educational objectives.

The CO-TIE Project is a cooperative program among the participating colleges and does not usurp the role of any of the participating faculty (ref. 6). One of the significant aspects of CO-TIE is the

* Cooperation Via Televised Instruction in Education

	AVIAN SCIENCE	BIOCO-TIE	ENGINEERING	MATHEMATICS	COMPUTER NETWORK	AUDIO NETWORK
Aims Community College, Greeley		●		●		●
Arapahoe Community College, Littleton		●	●	●	●	●
Colorado Mountain College (East), Leadville		●				
Colorado Mountain College (West), Glenwood Springs		●				●
Community College of Denver (Auraria)		●		●	●	●
Community College of Denver (North)		●		●	●	●
Community College of Denver (West)		●		●	●	●
El Paso Junior College, Colorado Springs				●		
Fort Lewis College, Durango			●			
Lamar Community College, Lamar		●			●	●
Mesa College, Grand Junction		●	●	●		●
Northeastern Junior College, Sterling	●	●	●	●	●	●
Otero Junior College, La Junta	●	●	●	●	●	●
Rangely College, Rangely		●		●		
Trinidad State Junior College, Trinidad		●	●	●	●	●

● Indicates program activity on campus

COLORADO STATE UNIVERSITY COOPERATION WITH HIGHER EDUCATIONAL INSTITUTIONS

FIGURE 2

involvement of the cooperating college faculty in the design of courses, laboratories and curricula. Among the significant activities included in the overall CO-TIE program are:

Avian Science -- Avian science became a part of the CO-TIE program in January, 1971, with the offering of a course related to poultry science and practice.

By offering video-taped lectures supplemented with other autotutorial materials, up-to-date scientific information about the poultry industry is presented to students who might otherwise not be able to obtain the information at the two-year college.

The avian science program for freshmen and sophomores provides video-taped lectures, a coordinated textbook and a laboratory manual, audio tape-color slide packages supporting laboratory presentations, and permanently preserved specimens of laboratory materials.

This type of autotutorial course offering is useful to a community college which may not be able to offer a curricula as broad as desired.

BIOCO-TIE -- In January, 1971, a new CO-TIE program came into being. BIOCO-TIE (Biology Core via Televised Instruction and Experimentation) is a cooperative program involving Colorado State University, the University of Colorado and thirteen two-year colleges in Colorado (ref. 7). Appendix C gives more details.

Colorado has a large reservoir of teaching talent among the biology faculties of community colleges. Through the use of video tape produced at CSU, project BIOCO-TIE allows these faculties to employ effective audiotutorial techniques in biology instruction.

Color video tapes, 5 to 20 minutes in length, are produced at CSU studios to provide visual support of classroom presentations at the colleges. A mobile television van is utilized to make recordings in the field, in laboratories and other locations. The color video tape recordings are produced in CSU's television studios utilizing techniques specifically designed for illustrative and demonstrative materials. Slides, transparancies, audiotapes and motion picture materials for auto-tutorial booths are also provided for both classroom and laboratory activities. These visual materials assist the colleges in providing the second year of a core curriculum in biology for their sophomore students.

Community college faculty participate in all aspects of the BIOCO-TIE program, including determining content of the tapes and participating in the making of tapes. In addition, the program draws from a resource of 450 biology-related faculty members and extensive laboratory and research facilities at CSU for preparation of the tapes.

BIOCO-TIE provides an opportunity for the faculty of colleges to work together in developing effective methods of teaching basic undergraduate core courses in biology. Of significance is the teacher updating aspect accomplished through briefing sessions conducted each quarter for the teachers. The briefing sessions are generally four to five days in duration. In essence, BIOCO-TIE is a teacher extending program, not a teacher replacement program (ref. 8).

Computer Network -- The computer center at Colorado State University houses a large high-speed digital computer (CDC 6400). The on-line mass storage capacity is 170 million characters. This computer can perform scientific and business data processing as well as multiprogramming, multiprocessing, time-sharing and data management tasks. Languages presently being supported are FORTRAN, BASIC, SNOBOL, COBOL, ALBOL, LISP, MIMIC, PERT, COMPASS, SIMSCRIPT and GASP. In addition, a program library of more than 1,000 fully documented programs and sub-routines has been developed, publicized and maintained.

Prior to 1971, the computer facilities available to serve the needs of Colorado's community colleges were nonexistent or severely limited. Consequently, students transferring to university programs

TABLE III

1972-73 ENROLLMENT DATA FOR BioCO-TIE COURSES

Quarter	Fall			Winter			Spring		
BY/BCT Course Number	201	202	203	201	202	203	201	202	203
INSTITUTION									
Colorado State University	199				206		102		168
Aims College	15				12				12
Arapahoe Community College	13			8**	12		5**		22
Community College of Denver									
Auraria Campus	6				4				0
North Campus	8				12				9
Red Rocks Campus	8				14				5
Colorado Mountain College									
East Campus	6				4				4
West Campus	6*				4				4
Lamar Community College	8*				5			7	0
Mesa College	18				15				14
Northeastern Junior College	15*				14				7
Otero Junior College	3				0				0
Rangely College	5				0				0
Trinidad State Junior College	4				6				6
TOTAL	314			8	308		107	7	251
GRAND TOTAL*** 985									

* Differs from Evaluation Report Number 1
** Offered on a tutorial basis, not a regular classroom session
*** 1973-74 Expect between 1100-1200

or jobs which make significant use of computers, were at a great disadvantage.

Through a statewide computer network funded jointly by the N.S.F. Office of Computing Activities (now Computer Innovation in Education Section) and the state of Colorado, eight of the participating CO-TIE colleges now have direct access to the complete capability of the digital computer on the CSU campus. A series of video tapes have been produced on such topics as Fortran IV and Cobol programming, file handling, and permanent files for use in the program. A sequence of summer institutes for teachers have helped introduce the new capability in an educationally sound manner.

Engineering -- Several basic courses taken by most engineering students in the sophomore year were not offered in Colorado community colleges prior to 1968. CO-TIE first focused on this deficiency. The program continues to offer three Electrical Engineering courses (Network Analysis) and one Civil Engineering (Fluid Mechanics) at the sophomore level. Regular campus classes are video-taped and used by the participating colleges along with live tutorial sessions which twice each week make use of the audio network and its blackboard-by-wire equipment for each course. It should be emphasized that the community college students are registered at their institution for credit. Therefore, in each CO-TIE class, an instructor at the community college monitors student progress and administers examinations, several of which are coordinated with the CSU instructors.

Modern laboratories for the study of electronics have been developed at each of the CO-TIE colleges. These facilities though small, are important additions. A matching fund grant for scientific undergraduate instructional equipment from the N.S.F. supported this cooperative effort (ref. 9).

Mathematics -- Another program, sponsored by the College Science Improvement Project of N.S.F., that used the SURGE/CO-TIE facilities was a cooperative program among the mathematics department at Colorado State University and the mathematics departments at five two-year colleges in the state. The objectives of the program were: (1) to improve the mathematical competence of the two-year mathematics staff; (2) to provide information on curricular matters.

The first objective was achieved by CSU offering two mathematics courses each term for the two-year college teachers. These courses were prepared in the standard SURGE fashion so the two-year college teachers could upgrade themselves without interrupting their job or moving to a new location. Approximately 75% of the staff members under 55 years of age took part in the program each term.

The second objective was accomplished by providing two conferences per year on topics of particular interest to the staff members. Well-known authorities were brought in to discuss and suggest ways that the particular topics could be introduced into their curriculum. These meetings were very well attended and resulted in a number of changes in the curriculum at the schools.

UNIVERSITY-HIGH SCHOOL COOPERATION: HI-TIE

CSU initiated a new project in winter of 1971 called HI-TIE which utilizes the same video taping facilities and studio-classrooms employed in the SURGE and CO-TIE projects. Through the HI-TIE project, CSU offers courses for university credit to both students and teachers of Colorado's secondary schools. Through these video-taped courses, secondary school teachers in a wide variety of areas will be able to complete in-service training and apply the credit earned to meet certification requirements. Students at the senior level will be able to embark on a university career prior to their high school graduation.

Frequently, high school students simply overtake or outrun the course opportunities provided in their high school curricula. Having exhausted the advanced courses or study possibilities, a student in the senior year may find a situation requiring less than full intellectual challenge. Currently, the geographical (and occasionally artificial) barrier which exists between high schools and universities almost precludes smooth transition between the senior year of high school and the first year of college.

Significant progress has been made in many areas of our country in recent years. For example, many high schools have designed flexible curricula which permit sophomores the opportunity to take junior and even senior courses. Freshman students in universities are routinely allowed to enroll in sophomore courses. Undergraduate students often earn graduate credit before receipt of their baccalaureate degree. One of the missing opportunities is the high school-university tie which would enable qualified students the chance to do college credit work on an elective basis.

A pilot program, presenting CSU's first ten-week freshman engineering course via video tape, was conducted with two Fort Collins high schools during the winter quarter, 1971. This course is an introduction to FORTRAN programing employing engineering problems as an instructional format. The pilot program was extended to five area high schools in the fall quarter, 1971, and a second course (sequential to the first) was added in the winter quarter. This past school year the program was announced to all high schools in Colorado with much interest expressed; however, due to a lack of facilities, only nine high schools participated with 40 high school students registered for CSU credit. (CSU loaned the high schools much of the equipment they needed, but only a limited amount was available.)

The response from the high school students who took the course, high school teachers and administrators, and CSU's own faculty has been encouraging. A recent evaluation of the program by the high school students and teachers indicated the basic problems revolve around equipment limitations. Also, the teachers have requested college math courses be offered so their advanced students can keep moving ahead. (Many high school teachers are qualified to offer the courses but minimum class-size limitations prevent the teaching of small classes.) Denver metropolitan schools have also indicated an interest on the part of many students to take a college course in horticulture.

The freshman engineering courses will again be offered in fall 1973 and winter 1974 with fifteen schools tentatively scheduled to participate. The program is still in a developing phase and each year more problems are eliminated. Expansion beyond the current somewhat limited operation is dependent upon acquisition of more equipment and, removal of the "pilot" nature of the program. The program is treated as experimental in most high schools and the teachers are volunteering their time and borrowing facilities from other recognized programs. A coordinate series of HI-TIE proposals have been prepared for preliminary review by faculty at Colorado State University, the University of Colorado, the University of Denver, and the University of Northern Colorado. The staffs of the Colorado Commission for Higher Education, Colorado Department of Education, State Board for Community Colleges and Occupational Education, Division of Communications, and the Board of Cooperative Services are actively involved in these proposals.

OTHER INNOVATIVE OFF-CAMPUS ACTIVITIES

In 1970 and 1971, much national publicity was focused on the unrest in the nation's prisons. Lack of educational opportunity was cited by prisoners and prison officials alike as being one of the contributing reasons for unrest. Educational programs are known to be useful in rehabilitation efforts of almost all penal institutions. In the past, most effort was put into vocational training; in fact, many prisons have extensive auto and electric shops wherein inmates may learn by on-the-job practice. In a few cases where prisons are located near college campuses, professors are offering evening academic classes to the prisoners in the classic mode used by extension programs.

From the experience in the SURGE and CO-TIE programs, CSU faculty members believe that the offering of university level courses to mature persons is possible using modern communication capability. In the spring quarter, 1972, the Department of Mathematics offered a 5 quarter-credit freshman mathematics course to inmates of the Colorado State Penitentiary at Canon City. The students were officially enrolled CSU students and received credit on a transcript upon successful completion of the course. The instructor employed video tapes of a campus class together with blackboard-by-wire sessions to illustrate concepts for his students who are located 150 miles away.

CSU intends to expand the prison project by offering courses to the inmates in several different disciplines. Complete programs are being planned so that it may become possible that persons enrolled in the "university within walls" will be able to obtain a good start toward a college degree. It will be necessary to find a small grant to cover the cost of tuition and books in order to encourage participation.

FACILITIES

The class sessions for the various outreach programs described herein are recorded in regular classrooms which have been specially equipped. A few graduate seminar sessions in management and all the recordings for the BIOCO-TIE activity are produced in the university's color production studio. Only the studio classrooms and supporting facilities used for the great majority of the off-campus instruction are described below.

Studio Classrooms -- One of the four CSU studio classrooms is illustrated in Figure 3. Each classroom is equipped with at least three cameras. A camera over the instructor's desk allows him to display written or illustrative materials. The instructor controls the overhead camera for functions such as zooming, focusing and composing. A monitor at the instructor's desk displays the picture being generated by the overhead camera. Another camera at the back of the room is mounted on a pan-tilt head; this camera is controlled by a technician in the central record facility. The technician may remotely pan-tilt-zoom and focus the rear camera. If the instructor goes to the three-panel chalkboard or walks around the room, the technician follows his movements. A wide angle, fixed camera at the front of the room is located to pick up a segment of the student class. By means of switches at the instructor's desk, the instructor selects the camera which is to be recorded. Two rooms have split-screen capability which allows the instructor to show two pictures on a single screen. Two monitors are located at the front of the room to allow students in the class to see all material presented via the overhead camera. A button is located in front of each student to activate an overhead microphone, which picks up the questions and other dialogue between the professor and students. Because students sometimes fail to push the microphone button, a similar button is located at the instructor's desk and the console at the recording headquarters.

Two of the studio classrooms are identical to that shown in Figure 3. These rooms each seat 30 students. A third studio-classroom was tailored for the needs of the highly interactive instructional methods which are common in the College of Business. This seminar room accommodates 16 students around a large oval table. The TV camera arrangement is similar to that outlined above. A fourth studio-classroom seats 125 students in a small, wedge-shaped auditorium.

<u>Control Console</u> -- Each classroom has an individual console at the recording facilities where a technician (frequently a work-study undergraduate student) is employed whenever an instructor is in the classroom. Figure 4 is a view of this area. The technician operates the back camera electronically from this location. He has telephone communications to the professor and can override the audio gain.

STUDIO CLASSROOM INSTRUCTOR'S CONSOLE

FIGURE 3

CENTRAL RECORDING CONTROL CONSOLE

FIGURE 4

Courses are not rehearsed, thus, the technician listens to the class presentation and takes verbal cues so as to display the best picture possible on video tape.

Record Area -- The record facility shown in Figure 5 consists of thirty-two video tape recorders and monitors on which tapes are made for the remote locations. An original video tape record is made as the class is conducted on-campus for each off-campus section. A switcher designed by the television staff is used to program the needed number of recorders for any given course. The number of tapes needed for each classroom varies from hour to hour.

Tape Delivery -- Each video tape in the inventory is given a number. A card catalogue is maintained on all tapes recording the location of each video tape within the system. Tapes are packaged in fiber shipping cases and addressed for the proper destination. Each evening the tapes are picked up by commercial courier (United Parcel Service) for delivery the next day at each remote location. Approximately 400 tapes are shipped to the remote locations weekly.

Audio Network -- Recitation and tutorial sessions are scheduled for CO-TIE, HI-TIE and the penitentiary participants over a dedicated audio network (see Figure 1). Over 1,000 miles of full duplex voice-grade lines of the Mountain Bell Telephone network are devoted to audio use in these projects. In addition to two-way audio communication being available for dialogue an electromechanical writing system located at CSU (Figure 6) is used to transmit graphic information to TV monitors at the off-campus locations. Slow-scan television is also used on an experimental basis between CSU and Mesa College, Grand Junction. The blackboard-by-wire and slow-scan TV utilize the same lines as used for the audio. An additional 1,000 miles of full duplex voice-grade lines are used to interconnect CSU with nine campuses participating in the computer network. Most of the lines used for the computer network are part of the state-owned microwave system

CENTRAL RECORDING FACILITY

FIGURE 5

CO-TIE COMMUNICATIONS FACILITY

FIGURE 6

originally built for the Colorado State Highway Patrol now operated by the Colorado Department of Administration, Division of Communications.

COMPUTER MANAGED LEARNING SYSTEM LABORATORY

The CSU Computer Managed Learning System (CMLS) Laboratory became operational in 1969 with a $225,000 grant from the Control Data Corporation. Fundamental research, rather than operational development, best characterizes this promising educational program. Experience to date in terms of student performance and motivation is very encouraging. Appendix D gives a good overview of work completed to date. The following description focuses on work now in progress under NSF Grant EC-30613.

The current program is designed to ultimately produce an operational prototype computer managed learning system that incorporates a wide range of delivery devices, an intrinsic form of instructional strategy, a natural form of author mode for the preparation of instructional lessons, and finally, the means required either to operate the entire system through a variety of general purpose computers while sharing the computer resources with other users or to operate with a stand alone mini-computer. The study and design is now underway of: (1) a centralized media complex which features a high-capacity natural image data bank consisting of still video images delivered to an individual learning carrel; (2) a student carrel built around a standard production color TV with local refresh; (3) a dedicated central computer facility which will drive the media equipment, execute the instructional logic, interpret communications from the terminals and maintain student files. The CSU work to date has actually demonstrated the feasibility and utility of this approach (refs. 29-40). The videofile technology is supplied by the Ampex Corporation. The key feature in the design is the local refresh capability to buffer the carrel TV set from the central videofile. The latter feature is critical if economical computer based instruction is to become a reality (ref. 41). While this brief discussion has centered on "hardware", the CSU faculty involved in CMLS have a significant commitment to the concurrent application of pedagogical principles.

DIFFUSION OF INNOVATION

Descriptions of the SURGE, CO-TIE and the Computer Managed Learning System programs have been widely distributed. During the past six years, ten journal papers describing various facets of these programs have been published (refs. 1-10) and presentations at many national conferences and meetings have been given (refs. 11-42).

CSU hosted a self-supporting symposia on SURGE and CO-TIE for three days in the summer of 1970 which was attended by 35 people. During the past four years, an average of twenty groups per month visit the campus to view the SURGE, CO-TIE and CMLS laboratory activities. To date, there have been a total of approximately 9,000 visitors from every state and many foreign countries. Among these visitors have been many college presidents and vice-presidents, state and federal legislators, state and federal bureaucrats and state department of education officials.

Federal and foundation officials frequently bemoan the fact that effective, economical practices are not immediately and widely adopted in education. We believe that a major cause, though undoubtedly only one of many, is the total lack of consideration which is given to capital outlay amortization in budget preparation. In a growing system, physical plant construction may be financed over several years by bonds. But rarely do public officials make a decision from alternatives which recognize that most technically based options are capital intensive and will not survive a budget exercise which focuses on minimum expenditure <u>that year</u>. State officials strive increasingly to control annual expenditures, and rightfully so, but "tight budgets" are wedded to fixed labor costs and perpetuate the spiraling costs of a labor intensive system. We believe that officials managing federal programs must recognize that innovational diffusion is greatly inhibited by our inability in education to plan capital expenditures properly.

ACKNOWLEDGEMENTS

The cooperative programs described herein have benefited from the active support of many faculty, administrators and students. A special "thank you" to President A. R. Chamberlain who has directed the introduction of instructional TV on the CSU campus since 1965 when he served as Executive Vice-President. Faculty commitment to specific goals has been a necessary prerequisite for CSU administrative support.

The Introduction listed the supporting grants of the Education Directorate of the National Science Foundation. The N.S.F. staff have assisted in numerous ways and we are pleased to acknowledge their help.

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APPENDIX A

ENROLLMENT RECORDS

Summer Quarter, 1973 Course Enrollments

(All courses SURGE unless otherwise noted)

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 570	Air Pollution	3	23	6	
BG 710	Human Relations Concepts	4	9	8	
CA 799	Research in Continuing Education	1	1	N.A.	
CE 795f	Special Studies in Structures	3	18	7	
EE 395	Special Studies in Electrical Engineering	1	29	N.A.	
EE 795a	Special Studies in Network Theory	2	3	N.A.	
EE 795e	Special Studies in Solid State Electronics	1	1	N.A.	
EE 799a	Master's Research in Network Theory	1	1	N.A.	
EG 587	Applied Biomedical Instrumentation	4	8	10	
M 420	Introduction to Complex Variables	3	4	20	
M 421	Introduction to Complex Variables II	2	4	17	
ME 495	Special Studies in Mechanical Engineering	4	10	9	
ME 495	Special Studies in Mechanical Engineering	8	23	8	
ME 574	Reactor Theory I	1	11	7	
ME 575	Reactor Theory II	1	1	4	
ME 799n	Master's Research in Industrial Engineering	3	3	N.A.	
ME 799p	Master's Research in Environmental Engineering	1	1	N.A.	
		43	150	96	
(17 courses)					

Spring Quarter, 1973 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AN 660	New Developments in Animal Science	1	14	N.A.	
AT 570	Air Pollution	4	7	16	
AT 630	General Circulation of the Atmosphere	1	3	24	
AT 763	Satellite Observation of the Atmosphere and Earth	1	8	13	
AT 797	Seminar in Atmosphere Science	2	10	N.A.	
BD 700	Computer Applications in Decision Making	4	14	19	
BF 720	Business Financial Policy	4	19	24	
BG 470	Advanced Business Statistics	3	8	25	
BG 476	Operations Research II	3	6	19	
BG 720	Management	6	39	10	
BG 788	Managerial Economics	2	7	20	
CA 799	Research in Continuing Education	1	1	N.A.	
CE 440	Environmental Health Engineering	3	8	35	
CE 550	Foundation Design	1	6	19	
CE 580	Imagery Interpretation/Engineering	2	18	6	
CE 606	Fourier Analysis of Geophysical Data	1	1	N.A.	
CE 724	Water Quality Hydrology	3	6	23	
CE 795a	Special Studies in Fluid Mechanics	1	1	N.A.	
CE 867	Structural Dynamics	2	5	5	
EE 412	Control Systems II	4	14	14	
EE 444	Electro-Acoustics	3	9	21	
EE 503	Active Network Synthesis	8	22	18	
EE 562	Energy Conversion II	2	4	8	
EE 682	Digital Signal Processing II	1	2	13	
EE 795h	Special Studies in Control Systems	1	4	12	
EE 799a	Master's Research in Network Theory	1	2	N.A.	
ME 468	Direct Energy Conversion	2	6	14	
ME 608	Stochastic Programming with Engineering Applications	4	10	4	
ME 799n	Master's Research in Industrial Engineering	3	8	N.A.	
M 421	Introduction to Complex Variables II	1	1	N.A.	
M 433	Applied Mathematics III	7	12	5	
(31 courses)		82	275	367	

Winter Quarter, 1973 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 300	Introduction to Weather and Climate	2	13	190	
AT 610	Radiative and Convective Energy Transfer	2	7	27	
BA 700	Managerial Accounting	6	31	22	
BF 485	Financial Environment and Operations	6	39	25	
BG 475	Introduction to Operations Research	7	23	68	
BG 570	Business Decision Making	11	70	36	
BK 485	Marketing Systems	3	14	15	
CE 544	Water Resources Planning	3	11	28	
CE 562	Fundamentals of Vibrations	2	9	19	
CE 622	Statistics in Hydrology and Hydraulics	3	8	25	
CE 642	Industrial Wastewater Treatment	2	5	4	
CE 767	Structural Analysis II	1	4	8	
CE 799b	Master's Research in Hydraulics	1	1	N.A.	
EE 411	Control Systems I	3	12	22	
EE 482	Digital System Design II	6	22	30	
EE 502	Active Network Synthesis	8	33	26	
EE 561	Energy Conversion I	3	4	12	
EE 621	Statistical Communications	1	6	4	
EE 681	Digital Signal Processing I	6	21	12	
EE 799a	Master's Research in Network Theory	1	2	N.A.	
ME 410	Engineering Economy	1	7	N.A.	
ME 467	Energy Conversion Fundamentals	5	19	24	
ME 532	Reliability Engineering	4	16	6	
ME 697	Seminar in Mechanical Engineering	1	2	14	
ME 788	Operations Research Models in Engineering Econ.	2	5	6	
ME 799h	Master's Research in Solid Mechanics	2	2	N.A.	
ME 799n	Master's Research in Industrial Engineering	1	2	N.A.	
M 420	Introduction to Complex Variables I	1	1	15	
M 432	Applied Mathematics II	7	22	73	
ST 309	Engineering Statistics	5	15	39	
(30 courses)		108	426	750	

Fall Quarter, 1972 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AE 551	Irrigation and Drainage Pumping Plants	1	5	15	
AE 553	Operation and Management of Irrigation Systems	1	3	15	
AT 589	Introduction to Atmospheric Science	5	24	18	
AT 600	Theoretical Meteorology I	3	8	26	
AT 797s	Seminar in Atmospheric Science	3	9	11	
BA 485	Accounting Concepts	4	25	32	*
BF 710	Financial Markets	3	12	15	*
BG 270	Basic Business Statistics	2	16	24	*
BG 430	Business and Its Environment	2	19	27	*
BG 485	Management Concepts	5	34	30	*
CE 422	Hydrology	2	5	44	
CE 754	Special Studies in Soil Mechanics	1	3	4	
CE 766	Structural Analysis I	1	3	10	
CE 780	Special Studies in Structures	1	2	10	
CE 799c	Master's Research in Hydrology and Water Resources	1	1	N.A.	
EE 422	Communications Systems II	2	8	14	
EE 481	Digital System Design I	7	44	34	
EE 501	Passive Network Synthesis	8	30	33	
EE 583	Microprogramming	5	30	2	
EE 701	Network Synthesis I	6	12	3	
EE 795n	Special Studies in Computer Systems	1	1	N.A.	
EE 799a	Master's Research in Network Theory	2	3	N.A.	
EE 899b	Doctoral Research in Electronics	1	1	N.A.	
M 431	Applied Mathematics I	5	21	20	
ME 372	Engineering Applications of Modern Physics	2	4	25	
ME 410	Engineering Economy	9	57	18	
ME 610	Special Studies in Budgeting	6	17	16	
ME 697	Seminar in Mechanical Engineering	1	2	13	
ME 795q	Special Studies in Biomedical Engineering	1	1	N.A.	
ME 799n	Master's Research in Industrial Engineering	3	4	N.A.	
PH 611	Methods of Mathematical Physics I	2	6	25	
ST 520	An Introduction to Probability Theory	6	16	43	
(32 Courses)		82	426	527	

*Fall Quarter, 1972 the College of Business entered the program. SURGE students may now earn a master's degree in business.

Summer Quarter, 1972 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 570	Air Pollution	4	16	N.A.	
EE 421	Communications Systems I	6	24	7	
PY 797a	Seminar in Industrial Psychology	1	4	N.A.	
ME 697	Seminar in Mechanical Engineering	2	14	18	
ME 795e	Special Studies in Energy Conversion	2	16	11	
ME 795f	Special Studies in Space Propulsion	1	14	12	
M 432	Applied Mathematics II	1	5	31	
(7 courses)		17	93	79	

Spring Quarter, 1972 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 570	Air Pollution	6	22	15	
AT 620	Climatology	3	8	27	
BG 476	Operations Research II	4	10	26	
BG 720	Management Seminar	4	28	23	
CE 550	Foundation Design	2	3	8	
CE 568	Advanced Structural Design	1	5	9	
CE 640	Sanitary Engineering, Unit Processes	3	10	10	
CE 753	Design of Earth Dams	3	8	11	
CE 761	Theory of Elasticity	2	6	10	
ED 528	Secondary School Reading Development	1	8	30	
EE 202	Network Analysis II	2	3	58	CO-TIE
EE 413	Control Systems III	2	3	11	
EE 421	Communications Systems I (For Summer)	3 est.	25 est.	21	
EE 432	Pulse Circuits II	7	18	19	
EE 503	Active Network Synthesis III	6	18	24	
EE 583	Digital Systems Design III	3	5	9	
EE 682	Digital Signal Processing II	7	20	5	
M 121	College Algebra	1	11	15	CO-TIE
M 433	Applied Mathematics III	6	11	21	
ME 420	Intermediate Mechanical Vibrations	3	6	7	
ME 432	Quality Control	7	14	14	
ME 495	Fortran Programming	6	11	0	HI-TIE
ME 586	Topics in Bioengineering	2	4	7	
ME 788	Operations Research Methods	3	10	2	
ME 824	Applied Thermoelasticity	2	5	6	
PY 797a	Employment of Minority Personnel	6	23	0	
ST 525	Time Series Analysis	2	8	16	
(27 courses)		97	303	404	

Winter Quarter, 1972 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 750	High Atmosphere Meteorology	1	3	0	
AT 788	Survey & Meteorological Satellites	4	18	7	
AV 101	Poultry Science	2	39 est.	38 est.	CO-TIE
BG 570	Business Decision Making	3	11	25	
BL 560	Research & Development in Industry	5	17	5	
CE 512	Hydraulics of Open Channels	3	17	15	
CE 602	Intermediate Fluid Mechanics	3	4	21	
CE 639	Sanitary Engineering, Unit Operations	3	14	11	
CE 760	Theory of Elasticity	2	6	14	
CE 795d	Studies in Mechanics	1	6	2	
ED 427	Foundations of Reading	1	9	30	
EE 201	Network Analysis I	4	8	62	CO-TIE
EE 202	Network Analysis II	1	1	69	CO-TIE
EE 412	Control Systems II	4	7	13	
EE 431	Pulse Circuits I	7	16	21	
EE 472	Solid State Theory	1	2	6	
EE 502	Active Network Synthesis	7	21	29	
EE 582	Digital System Design II	5	11	24	
EE 612	Physical Systems II	1	3	7	
EE 681	Digital Signal Processing I	7	28	5	
M 351	Numerical Analysis II	3	13	20	
M 432	Applied Mathematics II	5	15	17	
ME 532	Reliability Engineering	9	21	14	
ME 561	Applied Fracture Mechanics	2	11	13	
ME 585	Cardiovascular Biomechanics II	2	3	8	
ST 309	Engineering Statistics	8	26	33	
WS 682	Remote Sensing of Natural Resources	2	2	13	
(27 courses)		96	332	522	

Fall Quarter, 1971 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AE 528	Groundwater Hydrology	2	10	28	
AT 300	Weather & Climate	1	6	65	
AT 589	Introduction to Atmospheric Science	5	20	22	
BG 475	Introduction to Operations Research	7	39	35	
BL 400	Production Planning & Control	4	11	22	
CE 560	Advanced Mechanics of Materials	3	9	16	
CE 601	Intermediate Fluid Mechanics	4	6	25	
CE 638	Sanitary Engineering, Unit Operations	4	23	7	
CE 866	Theory of Thin Shells	1	9	9	
ED 500	Principles and Practice of Guidance	1	9	30	
EE 201	Network Analysis I	1	1	87	CO-TIE
EE 411	Control Systems I	4	17	10	
EE 471	Solid State Theory	1	4	8	
EE 501	Passive Network Synthesis	7	35	31	
EE 581	Digital Systems Design I	9	24	32	
EE 611	Physical Systems I	3	6	10	
EE 682	Digital Signal Processing II	2	7	5	
EE 701	Network Synthesis	8	29	4	
EG 101	Engineering Principles I	3	9	20	HI-TIE
M 350	Numerical Analysis I	3	10	19	
M 431	Applied Mathematics I	4	13	34	
ME 410	Engineering Economy	10	39	28	
ME 584	Cardiovascular Biomechanics I	2	10	8	
PY 797a	Employment of Minority Personnel	2	15	12	
(24 courses)		91	361	517	

Summer Quarter, 1971 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
EE 432	Pulse Circuits II	4	11	5	
EE 681	Digital Signal Processing I	2	9	7	
ME 697	Seminar in Mechanical Engineering	1	4	19	
ME 795a	Heat Transfer Seminar	1	12	12	
ME 795b	Compressible Flow Seminar	1	1	8	
ME 795h	Solid Mechanics Seminar	2	14	16	
(6 courses)		11	51	67	

Spring Quarter, 1971 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 630	General Circulation of the Atmosphere	2	5	20	
AV 101	Poultry Science	1	17	40	CO-TIE
BG 470	Advanced Business Statistics	2	3	20	
BG 476	Operations Research II	4	6	19	
CE 440	Environmental Health Engineering	5	24	31	
CE 761	Theory of Elasticity	1	7	10	
CE 768	Statically Indeterminate Structures	1	3	9	
CE 867	Theoretical Hydrology	2	11	8	
EE 201	Network Analysis I	1	1	0	CO-TIE
EE 202	Network Analysis II	2	5	69	CO-TIE
EE 203	Network Analysis III	1	17	40 est.	CO-TIE
EE 431	Pulse Circuits I	6	23	29	
EE 503	Active Network Synthesis III	7	31	30	
EE 603	Logical Design III	6	22	23	
EE 613	Physical Systems III	2	2	7	
EE 741	Wave Propagation	1	3	3	
M 332	Applied Mathematics III	4	8	53	
M 421	Complex Variables II	3	6	27	
ME 420	Intermediate Mechanical Vibrations	3	9	13	
ME 795x	Quality Planning	8	29	6	
ME 795qx	Topics in Bioengineering	1	5	5	
ST 522	Stochastic Processes II	1	5	39	
(22 courses)		64	242	501	

Winter Quarter, 1971 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 610	Energy Transfers	2	11	33	
AV 101	Poultry Science	1	15	35 est.	CO-TIE
BG 570	Business Decision-Making	9	33	9	
BK 485	Marketing Systems	7	26	26	
CE 544	Water Resources Planning	2	12	27	
CE 622	Statistics in Hydrology	2	7	18	
CE 760	Theory of Elasticity	4	8	12	
CE 765	Theory of Elastic Stability	3	10	5	
CE 767	Statically Indeterminate Structures	2	6	10	
CE 795f	Numerical Computer Methods	4	7	17	
EE 201	Network Analysis I	2	5	81	CO-TIE
EE 202	Network Analysis II	2	18	97	CO-TIE
EE 472	Solid State Devices	1	7	8	
EE 502	Active Network Synthesis I	8	44	39	
EE 602	Logical Design II	8	34	34	
EE 612	Physical Systems II	2	7	9	
EE 702	Network Synthesis II	3	9	0	
M 331	Applied Mathematics II	4	8	60	
M 420	Complex Variables I	4	13	37	
ME 697	Cost Effectiveness Analysis	7	55	42	
ME 795hx	Cardiovascular Biomechanics	1	5	5	
ST 521	Stochastic Processes I	1	5	49	
WS 680	Remote Sensing of Natural Resources	1	9	16	
(23 courses)		80	354	669	

Fall Quarter, 1970 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
BG 475	Operations Research I	4	15	21	
BL 540	Automation	7	52	5	
CE 200	Elementary Mechanics of Fluids	1	4	39	CO-TIE
CE 766	Statically Indeterminate Structures	3	12	11	
CE 795fx	Finite Element Method	3	19	2	
CE 795hx	Water Resources Engineering	3	17	7	
EE 201	Electrical Networks I	3	19	126	CO-TIE
EE 471	Solid State Theory	1	11	10	
EE 501	Passive Network Synthesis	8	51	39	
EE 601	Logical Design I	7	41	33	
EE 611	Physical Systems I	4	20	6	
EE 701	Network Synthesis I	3	13	3	
M 330	Applied Mathematics I	4	11	17	
ME 410	Engineering Economy	9	77	33	
ME 424	Advanced Dynamics	3	18	9	
ME 697	Information Systems	6	25	1	
ME 795fx	Mathematical Optimization	2	2	0	
ME 795hx	Cardiovascular Biomechanics	2	10	0	
ST 410	Probability Theory	4	10	35	
(19 courses)		77	427	397	

Spring Quarter, 1970 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 200	Introduction to Weather & Climate	2	6	17	
BG 470	Advanced Business Statistics	5	20	24	
CE 568	Advanced Structural Design	2	5	7	
CE 714	Hydraulic Structures	3	4	12	
CE 761	Theory of Elasticity	3	19	3	
EE 202	Electrical Networks II	2	10	78	CO-TIE
EE 203	Electrical Networks III	3	9	45	CO-TIE
EE 643	Electromagnetics III	1	3	2	
EE 795a	Network Theory	7	23	3	
M 430	Vector Analysis	5	24	30	
ME 432	Statistical Quality Control	5	20	11	
ME 451	Compressible Fluids	1	4	15	
ME 727	Continuum Mechanics	2	7	9	
ME 795f	Topics in Linear Programming	6	25	1	
ST 432	Mathematical Statistics	4	9	22	
WS 697	Seminar in Remote Sensing	2	6	6	
(16 courses)		53	194	285	

Winter Quarter, 1970 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
BG 475	Operations Research	7	48	27	
BG 570	Business Decision Theory	8	58	36	
CE 400	Applied Mechanics	1	6	25	
CE 544	Water Resources Planning	2	2	28	
CE 562	Fundamentals of Vibrations	6	31	10	
CE 712	Hydraulic Structures	1	3	23	
CE 760	Theory of Elasticity	3	22	2	
EE 201	Electrical Networks I	3	12	87	CO-TIE
EE 202	Electrical Networks II	3	12	82	CO-TIE
EE 402	Passive Network Synthesis	6	26	32	
EE 472	Solid State Devices	2	3	11	
EE 642	Electromagnetics II	1	4	3	
EE 702	Network Synthesis II	2	6	5	
M 435	Engineering Mathematics II	6	34	28	
ST 431	Mathematical Statistics	6	20	22	
WS 680	Remote Sensing of Natural Resources	5	32	10	
(16 courses)		62	295	262	

Fall Quarter, 1969 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
CE 200	Elementary Mechanics of Fluids	1	6	22	CO-TIE
CE 513	Computer Methods in Hydraulics	1	9	7	
CE 560	Advanced Mechanics of Materials	3	23	17	
CE 812	Erosion & Sedimentation	2	5	23	
EE 201	Electrical Networks I	3	13	105	CO-TIE
EE 401	Passive Network Synthesis	5	27	5	
EE 471	Solid State Theory	1	2	16	
EE 651	Ionized Gases	1	4	4	
EE 701	Network Synthesis I	3	12	6	
EE 741	Electromagnetic Theory	2	6	4	
M 420	Complex Variables	1	4	14	
M 434	Engineering Mathematics I	9	38	24	
ME 410	Engineering Economy	7	79	13	
ME 444	Heat Transfer	1	2	32	
ME 532	Reliability Engineering	6	31	3	
PH 465	Introduction to Qauntum Mechanics	1	3	13	
ST 410	Probability Theory	10	89	28	
(17 courses)		57	353	336	

Spring Quarter, 1969 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 630	General Circulation of the Atmosphere	3	9	23	
BG 370	Advanced Business Statistics	4	17	20	
CE 716	Advanced Hydraulics of Open Channels	3	11	5	
CE 724	Water Quality Hydrology	1	4	11	
CE 813	Potamology	2	4	23	
EE 202	Electrical Networks II	4	12	98	CO-TIE
EE 203	Electrical Networks III	2	4	38	CO-TIE
EE 433	Pulse Circuits	3	5	23	
EE 795a	Special Studies	4	20	9	
M 440	Fourier Series, Boundary Problems	5	18	46	
ME 432	Statistical Quality Control	7	38	16	
PH 727	Electromagnetic Theory III	1	1	6	
PY 440	Industrial Psychology	8	88	25	
PY 558	Human Factors of Systems Design III	2	23	3	
ST 284	Introduction to Numerical Methods	9	50	104	
(15 courses)		58	304	450	

Winter Quarter, 1969 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 751	Physics of the Upper Atmosphere	2	5	15	
BG 475	Operations Research I	11	100	14	
BL 485	Production Concepts	3	56	29	
CE 400	Applied Mechanics	1	10	14	
CE 512	Hydraulics of Open Channels	5	6	15	
CE 562	Fundamentals of Vibration	1	3	15	
EE 201	Electrical Networks I	4	24	106	CO-TIE
EE 202	Electrical Networks II	2	8	93	CO-TIE
EE 402	Active Network Synthesis	4	28	62	
EE 432	Pulse Circuits	2	9	33	
EE 602	Logical Design	4	25	10	
M 421	Applications of Complex Variables	3	11	42	
M 430	Vector Analysis	1	5	42	
ME 495	Special Studies	4	17	2	
ME 532	Reliability Engineering	5	17	6	
PH 726	Electromagnetic Theory II	1	1	5	
PY 557	Human Factors in Systems Design II	3	27	1	
(17 courses)		56	352	504	

Fall Quarter, 1968 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 620	Fundamentals of Climatology	2	5	21	
BL 540	Automation	6	64	12	
CE 200	Elementary Mechanics of Fluids	1	4	25	CO-TIE
CE 766	Statically Indeterminate Structures	1	7	16	
CE 812	Erosion and Sedimentation	2	15	22	
EE 201	Electrical Networks I	2	17	99	CO-TIE
EE 401	Passive Network Synthesis	4	26	39	
EE 431	Pulse Circuits	2	13	45	
EE 601	Logical Design	4	52	11	
M 365	Matrices and Determinants	1	7	46	
M 420	Complex Variables	3	9	53	
ME 410	Engineering Economy	7	79	7	
PH 725	Electromagnetic Theory I	1	4	6	
PY 556	Human Factors in Systems Design I	3	50	5	
(14 courses)		39	352	407	

Spring Quarter, 1968 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 742	Tropical Atmosphere	3	7	17	
BL 490	Manufacturing Concepts	7	47	26	
CE 795f	Vibration Fundamentals	2	7	0	
EE 424	Network Synthesis	4	24	12	
EE 515	Advanced Pulse & Digital Circuits	4	16	14	
M 435	Engineering Mathematics II	6	17	13	
ME 432	Statistical Quality Control	8	81	14	
ME 719	Optimal Control Theory	2	7	4	
(8 courses)		36	206	100	

Winter Quarter, 1968 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
AT 670	Atmospheric Constituents	2	9	15	
BG 475	Operations Research I	7	82	23	
BL 560	Research & Development in Industry	4	57	4	
CE 400	Applied Mechanics	2	9	5	
CE 562	Fundamentals of Vibration	3	16	14	
EE 458	Pulse Circuits	5	24	30	
EE 511	Network Synthesis	3	12	15	
M 434	Engineering Mathematics I	5	18	17	
ME 718	Optimal Control Theory	4	20	9	
(9 courses)		35	247	132	

Fall Quarter, 1967 Course Enrollments

Course Number	Course Title	Off-Campus Locations	Off-Campus Students	On-Campus Students	Notes
EE 452	Pulse Circuits	4	34	N.A.	
EE 510	Network Synthesis	2	15	N.A.	
ME 410	Engineering Economy	6	127	N.A.	
ME 417	Automatic Controls	3	13	N.A.	
(4 courses)		15	189	N.A.	

Recapitulation

Quarter	Number of Courses	Off-Campus Students	On-Campus Students
Summer, 73	17	150	96
Spring, 73	31	275	367
Winter, 73	30	426	750
Fall, 72	32	426	527
Summer, 72	7	93	79
Spring, 72	27	303	404
Winter, 72	27	332	522
Fall, 71	24	361	517
Summer, 71	6	51	67
Spring, 71	22	242	501
Winter, 71	23	354	669
Fall, 70	19	427	397
Spring, 70	16	194	285
Winter, 70	16	295	262
Fall, 69	17	353	336
Spring, 69	15	304	450
Winter, 69	17	352	504
Fall, 68	14	352	407
Spring, 68	8	206	100
Winter, 68	9	247	132
Fall, 67	4	189	N.A.
	381	5932	7372

Key to Participating Departments

AE - Agricultural Engineering
AN - Animal Science
AT - Atmospheric Science
AV - Avian Science
BA - Business, Accounting
BD - Business, Information Systems
BF - Business, Finance
BG - Business, Management
BK - Business, Marketing
BL - Businesss, Administration
CA - Continuing Education
CE - Civil Engineering
ED - Education
EE - Electrical Engineering
EG - Engineering Courses
M - Mathematics
ME - Mechanical Engineering
PH - Physics
PY - Psychology
ST - Statistics
WS - Watershed Sciences

Course Numbering

100-299 Freshman & Sophomore courses
300-499 Junior & Senior courses
500-699 Graduate courses
700-899 Graduate courses

APPENDIX B

COST ANALYSIS OF SURGE PROGRAM

The institutional setting can greatly affect the costs of any program. In order to properly qualify the information to be presented concerning costs of the off-campus programs, a brief statement concerning the Colorado State University setting is in order.

Colorado State University in 1967 did not have a history of either off-campus general extension or evening courses offered on-campus for part-time students. Consequently, the university had no administrative superstructure to manage general extension. Faculty were not accustomed to extra pay for off-campus or evening instruction. When the SURGE program was initiated by the College of Engineering, the Dean of Engineering chose to integrate the activity into the resident graduate programs of the departments. The Dean of the Graduate School obtained approval from the faculty committees and faculty government for the changes of traditional rules necessary to accomplish this integration. The faculty, therefore, added the part-time students to regular classes with the full expectation that traditional standards of graduate student attainment would be met. It was also possible to obtain the full impact of increased faculty productivity without the burden of a new administrative structure.

On the other hand, the University had taken steps in 1965 to organize media support within the Office of Educational Media as a central service organization. The function of this organization is to provide University-wide media support through its five operating units: Audio-visual, Graphics, Motion Picture, Photographic and Television Services. The total level of expenditure of the Office of Educational Media for staff and expenses in 1972-73 was approximately $500,000.

When television was implemented on campus at Colorado State University in 1965, a television policy was adopted by the governing board which placed the responsibility within the Office of Educational Media for: general supervision of all TV programs; purchase, inventory and maintenance of all equipment; all operating funds for the production and distribution of televised materials for resident instruction. Professional staff were employed for the television operation. Moreover, staff of the Office of Educational Media had demonstrated a strong willingness and ability to deliver. Thus, the placement of this responsibility was not a function of authority but rather a means of obtaining a coordinated, well-managed program with an avoidance of splintering and duplication.

Projects such as SURGE, CO-TIE, HI-TIE and others have been smoothly integrated into an active campus program. There are several advantages to this procedure. Much test apparatus and other equipment needed for the on-campus program is available to be used for the new off-campus programs. One highly qualified television engineer is able to design the off-campus program components as well as the growing campus system of TV. Video tape, recorders and related items are bid in University-wide quantities, thus reducing cost. Technical standards and equipment compatibility is maintained and improved utilization of both facilities and staff is realized. As the off-campus programs at Colorado State University expand into many disciplines, the inclusion of such efforts under a single service organization continues to be advantageous. Of course, all academic decisions remain the responsibility of the academic departments and colleges involved.

The cost of instruction for the SURGE program which serves practicing engineers and professionals in industry can be estimated with precision, because the program has completed six years of operation and attained a relatively stable level of activity. The following discussion concentrates on this program although much of the information on the cost of operation is applicable generally to all regularly scheduled courses video taped for use off-campus.

Faculty productivity measured in terms of student-credit hours, increased significantly in SURGE courses. The five-year average enrollment of students per course is 16.2 on-campus and 18.2 off-campus. There has been no adjustment in faculty teaching schedules due to this additional load. Rather, grading and graduate assistant help has been supplied to accommodate the increased enrollment.

The "direct cost of instruction" on-campus in the traditional mode is defined here as the instruction cost (faculty salaries) divided by the total number of student quarter credit hours associated with that instruction. This index is frequently cited as a measure useful for comparing regional variations between similar schools and between various disciplines. Clearly, although a dominant cost in most instruction, this factor does not represent the total cost of instruction. The direct cost of instruction on-campus in the CSU College of Engineering averaged over all levels of instruction in 1972-73 is $37.45 per quarter student credit hour (qt. cr.). Comparable data gathered by Dr. F. E. Terman and averaged over seventy-one engineering colleges yields $49/qt. cr. (J. Engr. Ed., 59, pp. 510-514, (1969); a six per cent annual increase was assumed to update these data). It is widely recognized that graduate level instruction is appreciably more costly than undergraduate and that wide variations in this index are usually found between the physical sciences and social sciences. For the M.S. level SURGE courses which are predominantly in engineering and mathematics, the CSU direct cost of instruction on-campus has been estimated to be $65./qt. cr. This figure is viewed as a conservative estimate for graduate instruction which averages 16 students per course. Any effective, non-traditional instructional system would generally be expected to compete with $65./qt. cr. if introduced on-campus. We apply such a comparison directly to the off-campus instruction of the SURGE program.

The cost of the SURGE program can be divided into three broad categories: (1) amortization of equipment, recording space and tape; (2) operating cost of production, delivery and program administration; and (3) incremental direct instructional cost of adding off-campus students to existing classes. We discuss these cost categories in the following paragraphs in a manner which makes the scaling laws of the program clear. That is, we will focus on the cost of recording a class hour in a studio classroom plus the cost of making and delivering tape copies with instructional support.

Equipment, Recording Space and Tape -- The cost per hour of recording is dominated by the amortization of the $25,000 for the remodeling and equipping of a studio classroom and control console. Table B-1 gives the details. Assuming five-year amortization with six per cent interest and 1000 hours per year of utilization, we calculate $6./hr. Note that only the cost of the TV facility is considered, because a regular on-campus class must be held in a classroom, and we are interested only in the direct cost of adding off-campus students via video tape.

A video recorder and monitor ($800) was amortized over three years assuming 1000 hours/year of use and six per cent interest. The resultant cost is $0.30/hr.

An hour reel of 1/2-inch video tape purchased in large lots costs $20. An average life of 100 uses yields $0.20/hr. The video tape original copy which is costed here is not distributed to off-campus students, but rather serves as a redundant or spare copy to insure system reliability.

The central recording facility space which houses the control console and a single recording unit is 300 sq. ft. This space was valued at $30/sq. ft. and amortized over 40 years with interest. This cost increment is $0.60/hr.

The total cost in this category for recording an hours' class time is the sum of the above or $7.10/hr.

Each additional tape copy requires $0.30/tape for recorders and monitors and $0.20/tape for the tape inventory. That is, the incremental cost in this category for each additional tape is $0.50/tape.

TABLE B1

STUDIO CLASSROOM AND MASTER CONTROL STATION

Capital Outlay

(For Black and White TV Equipment)

3 TV Cameras @ 1,000	$ 3,000
1 Sync generator	1,000
1 Pan tilt control unit	1,100
5 TV monitors @ 160	800
2 Zoom lenses @ 1,100	2,200
Instruction desk with control unit, split screen generator, and back pack play back recorder	4,000
Electronic control, amplifiers, cables special room wiring	2,300
Master Control panel with TV monitors, switching unit	5,600
Studio classroom air conditioning and necessary remodeling	5,000
Total Cost	$ 25,000

Operating Cost of Office of Educational Media -- The basic operating budget for production and program management at CSU for the current level of activity (80 courses/year) is \$60,300. This budget includes fractional time of an administrator, a program coordinator and a TV engineer plus two full time TV technicians and a secretary. Other direct costs include student labor, supplies and spare parts, travel and telephone, and program correspondence. At the level of 80 courses per year or 2400 recording hours, this base operating budget is \$25.15/recording hour. Details are given in Table B-2.

A recent survey of both the CSU videotape system, the ITFS broadcast system of Stanford University and the microwave link of the University of California at Davis and the A.E.C. facility at Livermore showed these "overhead costs" to be dominant in all systems. (See: Loomis, H. H., Jr. and Brandt, H., "Television as a Tool in Engineering Education," Special issue of *I.E.E.E. Transactions on Education*, *E6*, Issue 2, pp. 101-109, May, 1973).

Each tape copy of an hour's length requires an additional \$0.50 for tape handling and \$2.50 for round-trip delivery by commercial courier. The incremental cost in this category for each delivered tape is \$3.00/ tape.

Operating Cost of Instruction -- The faculty does not receive any additional pay or work load allowance for teaching a regular campus class in the studio-classroom. So there is no instructional cost for the recording hour. Rather it is the instructional support of the off-campus students which must be estimated here. The marginal cost of adding 15 students to a 3 quarter credit course is assumed to be 10 hours/week of graduate teaching assistance to help the professor with all aspects of the instruction. This allowance amounts to \$1.00 for each off-campus student who views an hour length tape, or if we let S be the average off-campus enrollment in a SURGE location, \$1.00 S /tape. To this incremental direct cost we add an allowance

TABLE B-2

BASE OPERATING COSTS

			Present Level	Expanded Level
Administrator,	$24,000.	1/10 time	$ 2,400.	
		1/10 time		$ 2,400.
Coordinator,	$16,000.	1/2 time	8,000.	
		3/4 time		12,000.
TV Engineer,	$15,000.	1/5 time	3,000.	
		1/5 time		3,000.
TV Technicians	$10,800.	2 full time	21,600	
		3 full time		32,200.
Secretary,	$ 5,300	1 full time	5,300.	
		1 1/2 full time		8,000.
Student Labor, @ $2/hr		3000 hrs.	6,000.	
		6000 hrs.		12,000.
Travel and Telephone			3,000.	
				3,000.
Supplies and Spare Parts			8,000.	
				11,700.
Printing and Mailing Announcements			3,000.	
				3,800.
			$60,300.	$89,100.

Allocated to each master recording on an hourly basis, these cost factors are:

$\frac{60,300}{2,400}$ = $25.15/hr. Current operation of 80 courses annually.

or

$\frac{89,100}{4,800}$ = $18.35/hr. Expanded operation of 160 courses annually.

for secretarial support, supplies and telephone of $0.30 for each off-campus student who views a tape, or $0.30 S /tape. A travel allowance for the direct cost of faculty visits to the SURGE locations is $1.25/tape, independent of the number of students in a location but directionally proportional to the number of locations (or tape copies made each recording session).

The total cost of instructional operating expenses can be expressed in formula fashion as: ($.75 + $1.30S)/tape, where S is the average student enrollment in each off-campus section.

<u>Total Cost of SURGE Instruction</u> -- The factors outlined above are summarized in the following table in 1971-72 dollars:

	Dollars per Recording Hour	Dollars per Delivered Tape
Equipment, Space and Tape	7.10	0.50
Office of Ed. Media Operating Expenses	25.15*	3.00
Instructional Operating Expenses	--	1.25 + 1.30 S
Total	$32.25	$4.75 + $1.30 S

* Based on ability to operate at current CSU level of 80 courses/year. This value becomes about $18.35 for enlarged program of 160 courses/year.

The CSU unit costs of off-campus instruction for the 1971-72 SURGE programs can be computed from these cost factors. The following enrollment and program data are required:

Total Courses	=	69
Total Sections*	=	261
Total Off-campus enrollment	=	883

Therefore,

$$N = \frac{261}{69} = 3.78 \left(\frac{\text{sections}}{\text{course}}\right) \text{ or } \left(\frac{\text{tapes}}{\text{recording hour}}\right)$$

$$S = \frac{883}{261} = 3.40 \left(\frac{\text{students}}{\text{section}}\right)$$

and let C = 1.00 qt. credits granted for 10 contact hours of course work.

$$F = \frac{\left(\frac{\text{recording hours}}{\text{course}}\right) \cdot \left(\frac{\text{dollars}}{\text{recording hour}}\right)}{\left(\frac{\text{ave. off-campus student credits}}{\text{course}}\right)}$$

where $\left(\frac{\text{dollars}}{\text{recording hour}}\right)$ is subdivided into fixed cost/course hour plus variable costs/course hour.

$$F = \frac{(10C) \cdot \left(\$32.25 + [\$4.75 + \$1.30\ S]\ N\right)}{N \cdot S \cdot C}$$

$$F = \frac{322.5}{NS} + \frac{47.5}{S} + 13.$$

$$F = \frac{322.5}{(3.78)\ (3.40)} + \frac{47.5}{3.40} + 13.$$

$$F = \$51.97/\text{qt. cr.} \approx \$52./\text{qt. cr.}$$

* A section is a group of off-campus students meeting at a location and requiring a tape.

Recall that the on-campus instruction in these courses has a direct instructional cost of \$65./qt. cr. for an average course enrollment in 1971-72 of 15.6 students. The average cost of instruction for <u>both</u> on-campus and off-campus instruction is:

$$F_{ave} = \frac{15.6(65.) + 12.9(52.)}{15.6 + 12.9} = \$59/\text{qt. cr.}$$

Clearly, the program lowers the instructional cost from the point of view of the university and also increases faculty productivity. But it should be stressed that this is a very narrow view of the cost of this instruction. If the part-time student had commuted to campus during his regular work hours, the opportunity cost which is neglected here would have been large indeed -- perhaps, \$300./qt. cr.! Furthermore, the university may have been required to add campus classroom space and parking. Even more important, the cumulative cost of technical obsolescence to the national economy should be estimated because advanced engineering and management training frequently does not occur unless programs like SURGE are initiated.

A convenient graphical presentation of the SURGE program cost analysis is given in Figure B-1. The marginal cost per quarter credit hour produced (F) is shown as a function of the average number of students per section (S) with the total number of sections per course (N) shown as a parameter. In the CSU example detailed above, S=3.40 students/section and N=3.78 sections/course which yields F=\$59/quarter credit. It is worth noting that video based programs for practicing engineers such as SURGE are far removed from the classical ETV model. That is, rather than \$50,000/hour of production costs spread over millions of viewers, the televised engineering programs must operate at near zero production cost because the potential audience is small. In fact, the TAGER system of SMU in Dallas will televise a course for a total of 4 students, the Iowa State University videotape system sets a total enrollment minimum of 5, and the CSU record in this regard listed in Appendix A shows instances of taping for 2-3 total off-campus students.

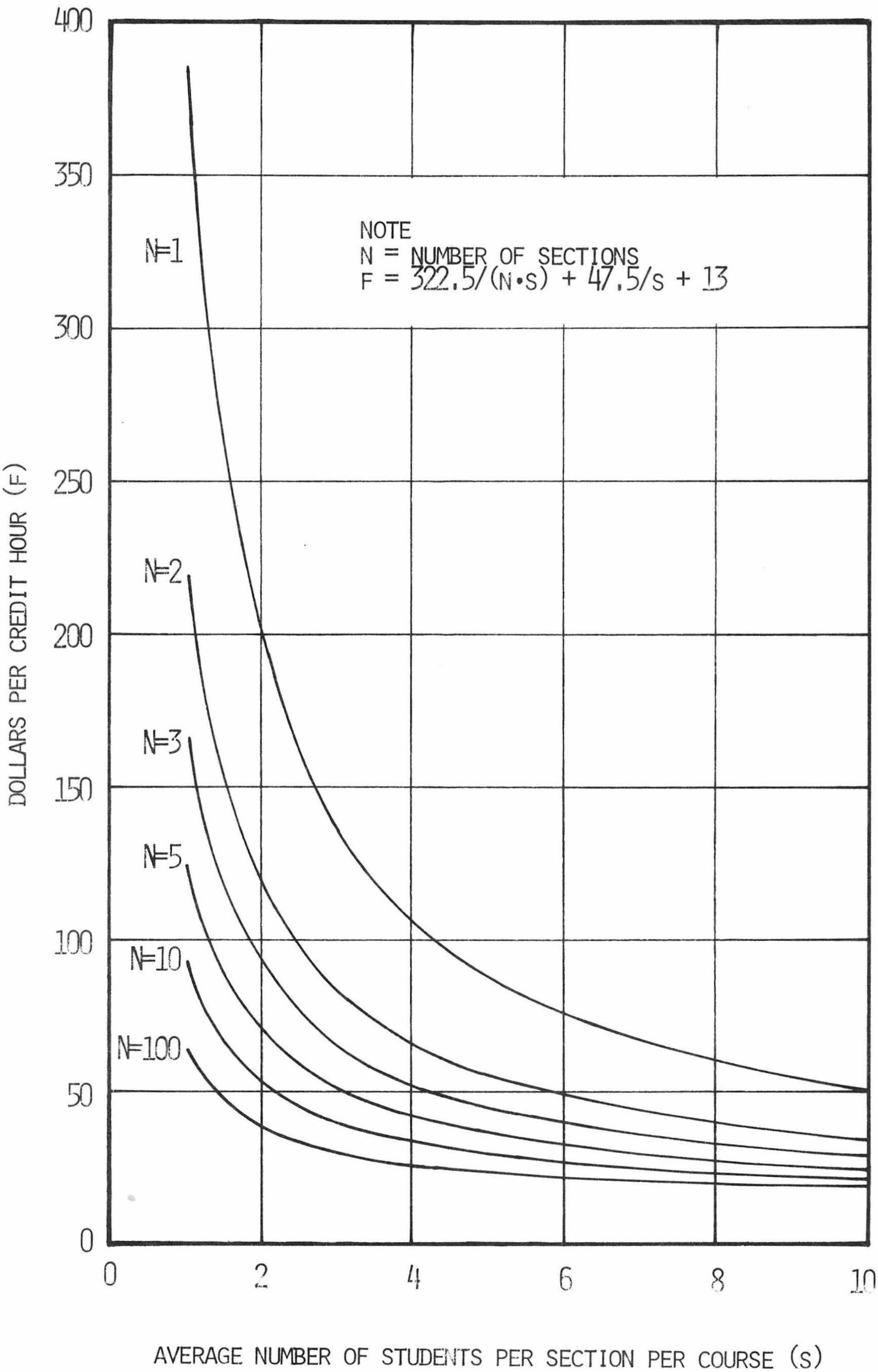


FIG. B-1 CSU OFF-CAMPUS TV COST ANALYSIS

The cost factors tabulated above are realistic and may be useful more generally than simply estimating the cost of a specific program in Colorado. For example, the decision whether to install a videotape system or an ITFS broadcast system, is a trade-off study between subtracting \$3.50 N (the cost of making and delivering tapes) and adding the amortized cost of the ITFS hardware on a course hour basis to the base value of \$7.10. For example, see "Technical and Economic Factors in University ITV Systems," by C. A. MartinVegue, Jr., A. J. Morris, J. M. Rosenberg, and S. E. Tallmadge, _Proceedings of the IEEE_, Vol. 59, No. 6, pp. 946-953, June, 1971.

APPENDIX C

BioCO-TIE: The Genesis of a Cooperative Curriculum Improvement Program

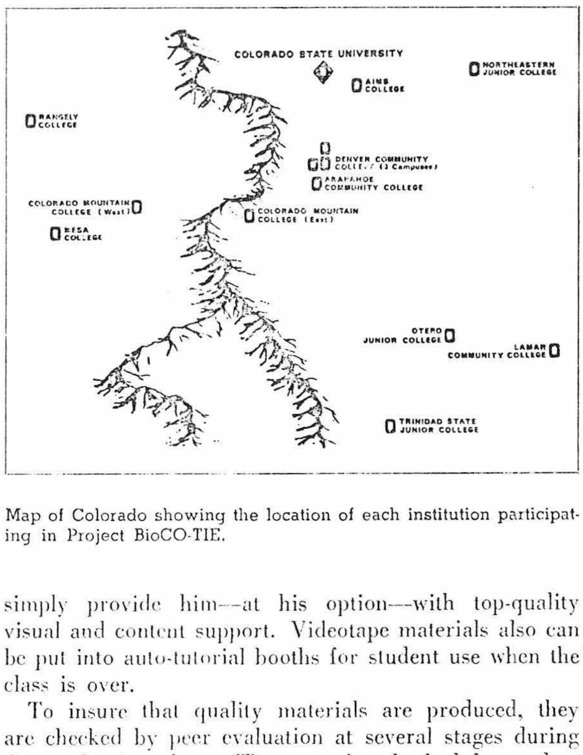
John Patrick Jordan, G. A. Johnson, W. J. Gore, and F. J. Vattano

Ask a lawyer and he will tell you that a cooperative arrangement between two or more parties which is not clearly beneficial to all parties isn't worth the effort it takes to draw it up!

Project BioCO-TIE[1] was founded upon that philosophy. It is a statewide cooperative program involving Colorado State University and the two-year colleges of Colorado. Its basic purpose is to assist the junior and community colleges in Colorado in providing the second year of a core curriculum in biology, thereby initiating a comprehensive program of science curriculum improvement across the state. The project focuses the attention of biologists on the lower division courses and brings together faculty members from the many institutions involved in teaching freshman and sophomore biology courses. At the same time, instructors at the two-year colleges are able to increase their teaching capabilities.

The idea originated when several biology instructors from various junior colleges across the state discussed the possibility of obtaining assistance with their second-year core courses, including use of the sophisticated laboratory facilities and equipment and the expertise of the biology faculty of a major regional university. Through Project CO-TIE[2] in the CSU College of Engineering, expertise had already been developed in areas such as videotape production, delivery systems, and communication among the various junior colleges throughout Colorado.

BioCO-TIE was developed and accepted by the 10 participating institutions. It involves the production of high-quality visuals using color television, slides, and transparencies. The material is studio-produced by professional television directors, producers, and graphic artists and packaged in small, single-concept modules. The unified, single-concept tapes emphasize the visualization of lesson materials but are not videotaped "stand-up" lectures. Tapes range in length from 7 to 30 minutes; they are kept brief to allow the instructor ample time to develop his own approach to the lesson. The materials



Map of Colorado showing the location of each institution participating in Project BioCO-TIE.

simply provide him—at his option—with top-quality visual and content support. Videotape materials also can be put into auto-tutorial booths for student use when the class is over.

To insure that quality materials are produced, they are checked by peer evaluation at several stages during the production phase. They are also checked for student acceptability and by student performance. Overall project evaluation is accomplished by a team which includes the staff of CSU's Human Factors Research Laboratory, the faculty of participating colleges, and a small group of external evaluators. External evaluators from across the country are organized through the American Institute of Biological Sciences' Office of Biological Education.

Dr. Jordan is associate dean, College of Natural Sciences, and Dr. Vattano is assistant academic vice president, Colorado State University, Fort Collins, 80521. G. A. Johnson and W. J. Gore are biology instructors, Northeastern Junior College, Sterling, Colorado 80751. *This article is adapted from the award-winning paper of the same title in the 1972 Gustav Ohaus-NSTA Program.*

[1] Acronym for *Biology Core* via *Televised Instruction* and *Experimentation*.
[2] Acronym for *Cooperation* via *Televised Instruction* in *Education*.

In the 1973-74 academic year, courses will cover "Population and Community Biology," "Cell Biology," and "Cellular and Developmental Biology." The Boettcher Foundation, a private Colorado corporation, funded a pilot program during the winter and spring quarters of 1971 which involved four two-year colleges and six separate classes. The first course in the sophomore level core, "Population and Community Biology," served as the pilot.

Ingredients for Success One of the most important results is the spirit of junior college/university collegiality—a spirit based upon principles that in hindsight seem obvious but that, unfortunately, are seldom brought to bear in cooperative programs. We now think we can identify those principles that will increase the probability of developing a successful cooperative program.

Included in these principles is the development of mutual respect, and appreciation that, although well qualified in their subjects, two-year college faculty are too often burdened by heavy teaching loads and limited facilities. The senior college or university can provide talent and facilities for development of visual support materials. It can provide specialized technical and professional assistance. Project BioCO-TIE is designed to be supportive, not to be a teacher replacement program.

The impetus for such a program should come from the junior college level, not from the senior college or university. Otherwise, it becomes just another example of outside "expert" interference.

In 1970, two faculty members from Northeastern Junior College at Sterling, Colorado, travelled throughout the state speaking to faculty biologists at each sister institution, outlining their goals, and gaining support for a program. Coordinators were selected by their colleagues to function as Project Co-Director and Junior College Coordinator.

Adequate planning for the needs of the junior colleges—the group to be served—is important in achieving coordination. Before the pilot program was initiated, a 4-day coordinating conference was held in which we reviewed philosophy, specific plans, materials, and a detailed survey of each and every class session. During the conference, faculty from both types of institutions participated in a number of videotaping sessions in order to identify those persons who had promise for television teaching. As a result, certain videotape sessions were made for inclusion in the course at the two-year institutions.

Flexibility must be allowed the junior college faculty. For each class session, a great variety of visual materials was prepared, some of which were subsequently duplicated in the form of full-color transparencies.

Just as communication plays a vital role in the initial planning, it continues to be of prime importance as the program functions. The program also uses a telephone network consisting of two lines—one for two-way voice and one for one-way graphics—between CSU and participating institutions. The system allows for conferences between students at the two-year institutions and faculty at CSU.

Some standardization among the participating colleges is necessary for evaluation purposes. But standardization must not compromise unnecessarily the freedom of the individual instructor. Optional support also is available in the form of examinations devised and graded at CSU. Some institutions have chosen to incorporate exam questions from participating campuses in their own examinations. Ultimately, there is a coordinated set of questions which provides for evaluation of the relative effectiveness of the program at each of the institutions.

Laboratory support should be flexible. For example, one institution may wish to receive only the laboratory write-ups, with a list of needed supplies and equipment; another may ask that the laboratory materials be boxed in proper amounts, with outlines and specific directions, and that the material be delivered at a specified time. If distances are not too great, the university can provide opportunities for the two-year college students to use facilities on the university campus.

Participating faculty should be provided opportunities to update their knowledge and skills. Institutes and selected courses can help. In our case, there is a program at the University of Denver, sponsored by the National Science Foundation under its College Science Improvement Program (COSIP), which neatly complements BioCO-TIE by bringing junior college teachers together for in-depth work in cellular biology, one of the key subjects in the second-year core courses.

The biology faculties of the two-year colleges like the program, because it provides high quality support which enhances their teaching effort. Senior college faculties like it, because students who come into their courses from the participating two-year colleges are better prepared. The students are pleased because of the ease of transferring course credits from the junior to the senior college.

One of the most important results of this program is the positive attitude of participating institutions. Essentially, the faculty and administrative support staff at CSU are saying to the two-year institutions, "We work for you. Tell us what you need and we'll try to deliver." And the two-year colleges are saying, "We recognize the benefits of having as a resource the very large biology faculty at CSU, together with the technical facilities and personnel to develop needed media support."

What did this pilot program cost? Each participating institution paid less than $1,000; a private foundation contributed $13,000 to partially defray production costs. In addition, time and effort by the faculty and staff of the participating institutions were contributed. In our judgment, this is a small price to pay for a high impact program.

The derivable benefits of this program are obvious: good curricular material, good resource faculty, good facilities to produce visual materials, a sound evaluation program, enthusiastic and dedicated teachers at the participating institutions, full involvement by all participating institutions, and an attitude of mutual respect among participating faculty. ■

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APPENDIX D

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educational technology®

A Technology-Based Educational System Using Computer Management

R.W. Hayman and W. Lord

Colorado State University has been working on the design and development of a computer-managed approach to education since April, 1969.

It appears that a certain product image has been too firmly attached to the terms CAI, CMI, CBE, etc.; an intentional effort is made, in this article, to avoid classification of the system being described according to any of these identifiers because the design has been to cut across the properties customarily ascribed to these various categories.

The emphasis of this article is on the description of a technology-based educational system which has been designed and implemented over the last three years. Discussion will be given in terms of an educational data base and a strategy to manage it, the media and communications techniques utilized, the hardware which contains the system and the software required to drive it. The design of the system takes its shape around certain characteristic problems associated with the traditional education process. These difficulties will be discussed, at the outset, along with the definition of an alternative educational model which is allowable only through a technological approach.

A Major Problem with Traditional Education

The operation of our traditional educational process does not provide for an intimate interaction with the student throughout his attempts to perform the educational objectives that have been prescribed for him. Much has been written about the importance of developing instructional *design* around a comprehensive statement of terminal behavior objectives—those attributes which a student should acquire as a result of a given learning experience. Increased attention to the objective approach will probably succeed in causing course outlines to be perfected and exams to be restructured, and this means that educational design will have been improved. However, little evidence is available to show that recognition of the importance of developing formal behavior objectives will have much impact on the *operation* of our educational process. Having specified the objectives more clearly, the traditional system still intends to put the student on his own as he attempts to write his poetry, compose his theme, or solve his calculus problems.

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One difficulty with this approach is that the main learning resource—the classroom lecture—is always out of phase with personal problems that occur in the student's attempts to perform the terminal objective activities. When problems occur, he must wait for the next offering of his primary resource to resolve them; even then, there is competition for recognition of personal problems. If we are interested in efficiency, from the learner's point of view, this situation is hardly ideal.

Requirements for formal testing programs arise out of this same situation. Since the operation of the traditional education model lacks the mechanism to communicate with the learner as he actually performs the terminal objective functions, the process must rely on tests over some statistically proper subset of the terminal functions in order to evaluate the student, reinforce or guide him. If we could monitor his effort on a continuous basis, testing would be largely unnecessary.

Another tendency which this situation encourages is that of overemphasizing the role of the learning resource by comparison to terminal objectives. We require the student to take advantage of the learning resource; in fact, his performance evaluation (final grade) may account for his attendance in class. Portions of the formal testing program may relate to elements of the resource (lecture) rather than to terminal objectives.

It is clear that the traditional education process lacks the resources of money, time and personnel which would be required to provide a solution for the problems described. However, events of the past decade have demonstrated at least the promise that modern technology, including communications media and the digital computer, could assist in the operation of a more complete educational cycle which would provide a continuous connection between learning resources and terminal behavior objectives. This prospect is examined in the section to follow.

A More Ideal Educational Model

Improvement in the manner of our traditional education system would require a model which is different by virtue of function rather than structure. The model would consist of two distinct components, the first of which is a set of activities which are, in themselves, the terminal behavior requirements. An aggregation of learning resources serves as the second component.

Any one of the learning resources should be made available for use by the student at any time during his attempts to engage the terminal performance activities. The traditional approach presumes that the student will need all of the available resources which are delivered, once and for all, at a time and in a manner that is convenient to the system. The strategy of the alternative model is more reactive than predictive. Because the model can *always* react, the education process can become highly personalized in its service to the individual student.

Educational resources must be organized in a manner that clearly establishes their hierarchical relationship with the various terminal performance activities. These relationships should be drawn clearly enough that the individual student can, for himself, locate particular resources that relate to a given terminal behavior function. While it may be true that the student's terminal behavior can be monitored on a continuous basis, the student's own intellect may be superior to any algorithm devised to identify the source of his difficulty at any point in time. If the student is aware of natural relationships between terminal behavior and learning resource, his own intellect is given the opportunity for expression.

In a paper presented to the Conference on Undergraduate Science Education in 1970,[1] Bunderson warns against the temptation to rely entirely on learner control of an educational system. Arguments presented in this article, and elsewhere, suggest that the student should be given wide latitude in the management of the learning resources, but that some central tendency path of flow should be established through the various elements of the model. This view has been adopted as the criterion for the strategy which will manage the model. The method of accomplishing this is given in a following section of the article, which deals specifically with management strategy.

There are to be no tests given or achievement evaluations made as the student engages the various learning resources. In fact, he will not be *required* to use the resources at all. It will be presumed that the student will quickly learn the value of a particular resource and will establish his own version of necessity to engage the resource as required support for achievement at the terminal objective level. The learner will be allowed to repeat resource activities as often as he may like and for whatever reason he may choose. It must be expected, however, that the learner will occasionally experience difficulty with a particular resource unit itself; accordingly, management strategy should provide a means to lead the student through cognitive interrelationships which exist among the various learning resources.

Theoretically at least, the new model could be designed to operate across boundaries of the normally autonomous course structure. Such boundaries now exist only as a convenience to management of the traditional classroom lecture form of learning resource. The traditional process cannot afford a formal reaction to the student whose present difficulty has root in some prerequisite course.

The Role of Technology

If the educational model proposed in the previous section has sufficient merit, it remains to devise a means for its implementation. As stated earlier, the traditional approach to education lacks the resources of money, time and patience which would be required to interact with the student in the manner described in the previous section. Moreover, it is unfortunate that the traditional classroom lecture cannot be made available on a timely basis, or with enough flexibility from the viewpoint of the learner. It may be true that the lecture will remain as the most efficient single learning resource, but it is unmanageable in the context of the model proposed.

There are many well-recognized signs that technological alternatives may function with a cognitive efficiency that is equal to the standard lecture system. Technology is a capital-intensive approach, which encourages and even demands that progress and improvement are cumulative. Because of this, there is every reason to expect continued improvement in the position of the technological learning resource relative to the classroom learning resource. Furthermore, technological costs are on the decline, and this picture should continue to improve. There is already some claim that technology such as CAI and educational television, considered as learning resources, are cost competitive with the traditional lecture resource, particularly at the level of higher education.

There is credible and forceful criticism of current attempts to replace the traditional classroom with technology. At least some of this criticism could be pointed at technological attempts to emulate the classroom-centered educational model, and therefore are criticisms of the traditional process, revealed and discernible because the technological model has been well organized and *widely exposed to view.* CAI, if undeveloped beyond the typical drill and practice form, can rarely be described as a complete educational process—although it has proven itself as an effective educational resource. These systems often include achievement tests to determine if the learner has used the resource properly, once and for all. That such a system affords the luxury of self-paced learning usually means that the student will be allowed to finish his lesson in 20 minutes rather than in one hour, because he works faster. On the other hand, he must usually wait until Wednesday for the next lesson to be made available. Educational television suffers from some of the same faults. It is undoubtedly an effective learning resource; potentially, one of the most effective resources yet devised. However, it can rarely be the terminal objective activity, nor can it interact with the terminal performances without benefit of some other interface with the student.

The conclusion to these arguments would indicate that there must be a more effective means of integrating a variety of learning resources with terminal goals and, in so doing, remaining within allowable bounds of acceptable financial structure. The remaining portions of this article describe attempts to accomplish this.

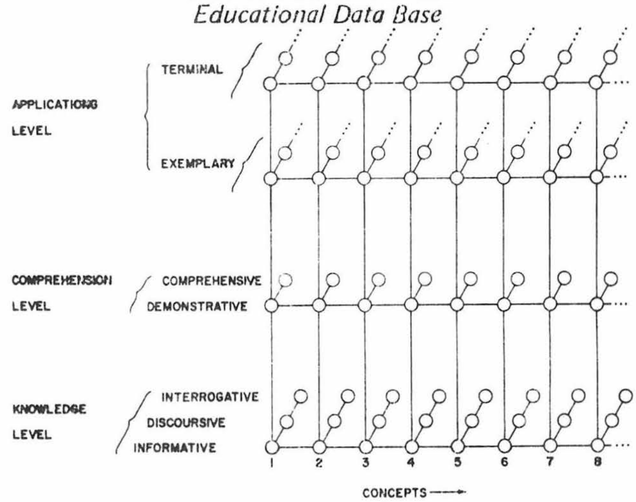
Implementation of the Technological Model

Descriptions which follow take particular form around the subject of vector algebra. However, the details of structure and management strategy have been planned with a view toward more general applicability. The digital computer is employed as the general manager of learning resource units, as interpreter of the terminal objective activities and as the interface between resources and objectives.

General management strategy is concerned with the selection of learning resource units and terminal behavior sets, and is largely independent of the contents of resource units and terminal sets. This feature allows the instructional designer to concentrate on subject matter content, forms of expression and other local

Figure 1

General Structure of the Educational Data Base



properties of a given instructional unit rather than on the decisions which may be taken to use the learning resource. In this way, the individual learning resource units bear much the same relationship to system management strategy as books and technical articles traditionally do to the instructor's prerogatives.

Educational Data Base

Instructional materials are organized into discrete functional modules and arranged according to a three-dimensional classification, as shown in Figure 1. This matrix represents most of the learning resources to be made available to the student and all of the terminal activities which relate to a particular instruction set. The horizontal dimension identifies the primary issues, or *concepts,* in the set. The vertical dimension represents the categories of the *cognitive domain,* as proposed by Bloom.[2] The third dimension specifies different types of treatment to be provided to each concept at each of the *cognitive levels.* The instructional designer writes his materials or specifies some action expected of the learner for each node in the matrix.

The top line of the application level represents a general statement of terminal objectives. Bloom defines application as "the use of abstractions in particular and concrete situations. The abstractions may be in the form of general ideas, rules or procedure, or generalized methods. The abstractions may also be technical principles, ideas and theories which must be remembered and applied."[3] This general statement is transformed into a specific terminal objective by identifying the particular abstractions to be mastered and the use to be made of them. In the data base matrix, the abstractions appear as concepts and the use to be made of these is described for the student at each of the matrix nodes located on the "terminal" line of the applications level. Several terminal nodes are provided for each concept and the student is allowed to select among these in satisfying some minimum number of objectives for each concept category.

In the case of the vector algebra data base, each terminal node is composed of:

1. An applications problem statement.
2. An explanation of the physics of the problem, for those who desire it.
3. An outline of the problem which transforms it into a collection of comprehension-level subproblems.
4. A complete solution of the problem.

The physical explanation is given, upon student request, at no penalty. Should the student be unable to perform, he is presented with the comprehensive outline and asked to attempt the problem again. Subsequent failure to perform results in discreditation of the student with respect to this particular exercise.

Bloom's complete cognitive taxonomy specifies six *cognitive levels:* knowledge, comprehension, application, analysis, synthesis and evaluation. This project has made no attempt to develop a strategy for management of a data base which includes the last three, or uppermost, of these. A wide range of traditional class offerings, including the domain of higher education, presently require no terminal development beyond the cognitive level of application; therefore the technological model developed here has wide potential, even with the restriction noted.

The resource components of the model are identified along the exemplary line at the applications level and along the comprehension and knowledge levels. Resource materials are always available to the student and he may use them repeatedly, or not at all. The model has a natural hierarchy of concept and cognitive level which is useful to the student in selecting among the resources for particular reasons of his own, although the management strategy also develops a unique program for each student, as will be discussed in the next section.

The use of Bloom's taxonomy seems particularly appropriate to this model because of its organizational inference and because of its functional nature. The taxonomy does not imply just how much comprehension will be required of a particular student in order for him to function at the applications level, but it does suggest the type of treatment that may be most useful in the treatment of difficulty in the application performances.

Primary characteristics of each of the sublevels of the model are given in Table 1.

In addition to those features discussed above, the resource component of the data base includes a computational support package and a blank common module, into which may be loaded standard batch-form computer programs. The idea of this last feature is to allow the user to access simulation and game programs from an available library, at any time he chooses and for whatever reason. Similarly, the computer mode feature operates as an instantaneous interrupt to whatever else may be happening at a given time and executes the standard operations of addition, subtraction, multiplication, division and exponentiation, and evaluates standard trigonometric and algebraic functions, including simultaneous equations.

Management of the Educational Data Base

Functional specifications on the management strategy are as follows:

1. Provide a normal path of delivery of the materials contained in the data base.
2. Allow the student to enter the path initially at any point he chooses and, subsequently, to skip about on the normal path at his own discretion.
3. Account for cognitive relationships among the resource elements of the data base as they may exist, in addition to those implied by the hierarchical structure of the system.
4. At any time, allow the student to access the computational support package and any simulation/game package that may be attached to the data base.
5. Monitor the student's performance at the terminal level and compose an individual program of remedy for any difficulty he may have.
6. Require the student to execute successfully some minimum number of subsets from the collection of terminal-level activities.

With all of the flexibility which these specifications afford, it is implied that any student may use single components or any collection of components provided, for reasons other than to meet the terminal requirements expected of the formal student.

Upon initial entry into the system, the student is given indoctrination on the organization of the instructional data base and is informed of the character of the set of terminal objective activities. He is also briefed on the use of control commands by means of which he is able to move about in the data base, according to his own pleasure. These preliminaries are conducted under computer control and consist of a five-minute videotape segment, a simulator package which allows the user to experiment with the system control commands and a dialogue which establishes user comprehension of the introductory materials. Figure 1, in this article, serves as the basis for the student indoctrination and will be referred to frequently in the discussion to follow here. This particular schematic has been named the *learning matrix.*

It is anticipated that students will come to the system with a wide variety of background in terms of cognitive achievement and concept exposure. Accordingly, the student is asked to pick his own starting position within the learning matrix; any node of the matrix, including some terminal objective activity, is an acceptable candidate. Upon completion of the first learning event (matrix node), the starting position is confirmed or denied on the basis of the student's feeling of comfort with the level of the material and its applicability to his particular case. A stable point of beginning, within the learning matrix, identifies a *cognitive base* and a *concept base.*

A pretest could be delivered, as a more standard and elegant method of establishing a beginning point for each student. However, this would require much of the student's time, relies too heavily on inferences which are

Table 1

Properties of the Cognitive Level System and Method of Delivery

1. *Knowledge*
   (a) Informative
   Function—Deliver fact, formula, definition, theorem, description or principle.
   Delivery Media—Combination of Cathode Ray Tube (CRT) character display and still imagery display on standard TV monitor.
   Student Response—Paging.
   (b) Discoursive
   Function—Amplification of fact, etc.; draw relationships between facts and discuss inferences.
   Delivery Media—TV monitor and headphones for audio. Black and white videotape is used at present. No single presentation to exceed five minutes' duration.
   Student Response—None required.
   (c) Interrogative
   Function—Question the student on fact, definition, etc. and draw the student out with respect to interpretation and interrelationships among the elements of the knowledge base.
   Delivery Media—Combination of CRT character display and TV image display.
   Student Response—Complete answers to questions via the CRT/keyboard console. Replies are acceptable in any format the student wishes to use; restricted only by the character set available on the keyboard. Response is recorded on hard copy but is not analyzed, by the computer, for content.
   System Response—Answers the question, side-by-side with student response. Learner judges his own performance and repeats (a) and (b) if he feels this is necessary. All responses are recorded on hard copy.
2. *Comprehension*
   (a) Demonstrative
   Function—Interpret the abstraction in the context of physical reality through a series of examples.
   Delivery Media—Combination CRT message and TV imagery.
   Student Response—Paging.
   (b) Comprehensive
   Function—Asks the student to translate, interpret and extrapolate abstractions into a variety of forms and into a variety of physical circumstances.
   Delivery Media—CRT message and TV imagery.
   Student-Systems Response—A running dialogue, with the computer performing multi-level branching to provide individual correction or reinforcement to student response. This particular treatment represents the standard notation of a familiar CAI drill approach.
3. *Applications*
   (a) Exemplary
   Function—Promote the use of abstraction in particular and concrete situations. This stage does not represent the terminal objective because the learner is informed of the particular abstraction required for a given application. Furthermore, the use of abstraction, other than the central issue, is explained in the applications statement.
   Delivery Media—CRT message and TV imagery.
   Student-System Interaction—The learner performs the required actions, in any way he chooses. He reports only final results. If the results are unacceptable, a cycle is established which converts the application problem into successively lower cognitive forms, with the student re-executing the application function at the end of each cycle.
   (b) Terminal
   Function—To require the use of some random combination of the entire assembly of abstractions in a variety of particular and concrete situations. The specific abstractions which apply are not identified for the learner.
   Delivery Media—CRT message and TV imagery.
   Student-System Interaction—Same as for the exemplary level. The student is not credited toward his objective until he performs the required application activity without benefit of having the activity redescribed in terms of some lower cognitive form.
   Selection Options—The student is allowed to select, from among numerous alternative application situations, those which are most appealing to his individual taste.
   Performance Criteria—The student must eventually qualify with a totally acceptable performance on some minimum number of activities taken from the available group.

not well understood and denies the use of the student's own intellect. The use of pretesting was rejected on these grounds.

From a particular starting position in the learning matrix, the student is moved along a simple path upward in the cognitive direction through the terminal level. The next higher ordered concept is then considered, beginning again at the student's cognitive base level. The terminal materials, located at the head of any one concept, actually involve random combinations of those concepts which lie to the left. For example, the terminal nodes for concept five involve some combination of the concepts one through five. The normal path through the system follows the two-dimensional hierarchical structure of the data base and is presumed to represent the most natural sequencing of materials for a wide range of system users. This path is modified for each individual student.

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At any time, the student may select a new position on the learning matrix. This transposition is accomplished through one of eight master control keys located on the user terminal. The controls allow the student to select any resource module or terminal activity and to move against the local program flow within an instruction module. A RETURN key will restore the user to his most advanced position on the base path.

The student may develop difficulty in the performance of some terminal objective activity; in this case, the system will detect that a problem has occurred. Alternatively, the user may inform the system that he has difficulty over any one of the instructional modules. In either case, the system logic identifies those learning resources or terminal performance activities which show the most direct relationship to the area of difficulty, and the learning path is immediately modified to include the remedial materials. It remains true that the student may elect not to follow the modified path prescribed by the system logic.

The basis for the system reaction to a student difficulty is constructed by the instructional designer. A binary association table is attached to each of the learning resources and terminal behavior modules and establishes the interdependency among the elements of the data base. As the student concludes his encounter with a given resource or terminal activity, the contents of that particular association table are either added to or deducted from the performance record which is kept for each student. This record, which is stored in the format of Figure 1, develops highs and lows which point to the student's strength and weakness. These data are analyzed by the system logic to produce modifications to the normal path for each student, on an individual basis. The original binary association tables are independent from the other details of programming for the instructional modules. Because of this, any instructional program module may be altered, entirely replaced or even deleted without interaction with the basic management strategy. As experience is gained through use of a particular set of instructional materials, the individual interaction tables can be easily modified to increase or decrease attention to a particular instruction module without having to interact with either the contents of the various instruction modules or with the basic management strategy.

Aggregate requirements on the terminal performances of the students are set into the system parametrically and may be adjusted easily as experience might direct. Again, these adjustments require no interaction with instructional content or revision to management logic.

Media and Communications

A typical student learning station is shown in Figure 2 and consists of one standard CDC 211 (TREND) Communications terminal, one video monitor and one headset for audio reception. At any point in time, the system response will fall into any one or combination of four categories:

1. An alphanumeric display which delivers the result of unique computer processing, such as an answer to numerical operations requested by the student.
2. An alphanumeric display of some prepared text which has been stored on a digital mass memory device.
3. Response prepared and stored on videotape representing live action and including sound.
4. Response prepared as a single image (graph, data table, photograph, etc.) and stored on a random access video disc.

Figure 2

Student Learning Station

The choice of delivery media to be used for a given purpose rests with the instructional designer, who has the flexibility of choosing any one or combination of media at any point in the instructional program.

All media sources are centrally located and a single media unit is generally capable of servicing several terminals without substantial delay in delivery to any one terminal. Additional description of system hardware is given in a section devoted specifically to this purpose.

Student response to the system is generated on the keyboard attached to the CRT display as shown in Figure 2. In the design of the communications system, it was considered essential that the user be allowed to represent his thoughts in a natural language format and that interpretation procedures be provided to allow for alternative forms of expected response. Interpretation of student input is accomplished in one of two ways. A numerical response is checked against a single answer base, with tolerances allowed on either side of the base. Word strings, including a complete sentence entry, are searched for key words drawn from a dictionary prepared exclusively for each student response point. The local dictionary contains alternative acceptable forms of key words, including any anticipated misspelling. The communications processing procedure provides for program branching in several different directions based on the expectation of several distinctly different responses at a given point. For example, action 1 is taken if the student says, "The car is green"; action 2 is taken if he claims the car is red, etc. It is also possible to distinguish between statements containing different combinations of key words; for example, the student who says, "I am tired" is in a distinctly different state from one who says, "I am not tired." Through the consecutive search through two key-word dictionaries, the proper distinctions can be made between these two statements–the key words being *tired* and *not*.

Currently, no attempt is being made to employ a general purpose spelling analysis algorithm. Such procedures commonly require considerable computer memory and consume relatively large amounts of processing time by comparison to the key word search procedure, even where large dictionaries are employed. Evaluation currently in process will have to confirm the acceptability of the latter approach.

Hard copy records are kept on all student transactions with the system. These records contain both the student responses and those of the system, in the natural order of their development. Records are not physically developed at the student terminal but are stored on a mass memory device at the central computer and transcribed to paper copy as required.

The project is currently supporting work on procedures to enable the interpretation of voice response within a limited word vocabulary. Research to date has produced a process which is technically feasible and highly reliable. Reliability is achieved by measuring the voice signals for each student against his own vocabulary, previously prepared and stored in the system.

Project personnel are not interested in voice analysis as an easy means of communication compared to the use of keyboard response. The main reason for skepticism is in the very limited vocabularies that can currently be treated in this way. However, early results of this research indicate that it may be possible to discriminate among a significant range of temperamental states of the speaker. It may be possible, for example, to determine if the student is frustrated, angry, disinterested, enthused, etc., through analysis of his voice pattern. This capability could add another valuable parameter to the instructional strategy which can only react, at present, to the cognitive condition of the student.

Hardware

1. Computer. The Colorado State University computer managed learning system employs a CDC 6400 digital computer, ten peripheral processors, three 841 disc drivers and one 6603 rotating mass storage device. A standard CDC operating system, SCOPE 3.3, is used to drive the system. A 6681 data channel converter and a 3290 inquiry/retrieval controller connect the student learning stations and the media center to the main computer complex.

The learning system is operational at the same time that the computer is servicing a relatively heavy load of standard batch entry jobs. The machine is fast enough that acceptable service is provided to both the batch job stream and the interactive instructional programs. Recent measurements show that the average time required to service a student action at the interactive terminal is approximately nine-tenths of a second.

2. Student Stations. Four student terminals have served the needs for system design, development and testing and for evaluation of instructional material. This number must, of course, be increased in a fully operational version of the system. A single student station consists of a CDC 211-4 interactive terminal equipped with standard keyboard and Cathode Ray Tube character display, one standard TV monitor and one set of headphones for audio. Hard-wire connections are used to link the interactive terminal to the computer and the TV monitor and audio to their respective media sources. The interactive display screen can write up to 1000 characters in approximately 1/30 of a second and can be selectively erased and written.

3. Video Disc. A rotating video memory disc is used to store a wide variety of fixed images to provide visual reinforcement at any point in an instructional sequence. At present, permanent storage is provided for 450 video images which are recorded on the top surface of the rotating disc. A flying head searches out the required image and transfers the signal to the underside of the disc, where a fixed buffer head provides final reading-out to a given TV monitor located at the student station. The video image is continuously refreshed from its own buffer so that a given display may be held for an indefinite period of time without further attention from the computer or preventing access to some other image required at another student station. The disc unit can accommodate up to 21 buffer heads. The maximum access time for any image recorded on the master storage surface is approximately two seconds.

An inexpensive TV camera is used to write the original video images on the master surface of the disc. The desired visual is simply sighted with the camera, whose output is switched to a particular disc track on the master surface through the flying head. Master images may be altered, rearranged or replaced at will and at negligible cost.

The video disc is an adaptation of commercial equipment presently being used to provide instant replay of live action, particularly sports events. Ampex Corporation manufactures this equipment and produced the modified version for this project.

4. Videotape Equipment. Any one of the resource modules shown in Figure 1 may, at the discretion of the instructional designer, consist of audio/video presentations. Practice to date has been to restrict the length of any one of these presentations to three or four minutes; however, the reasons for doing so are matters of instructional design preference rather than any particular limitation imposed by equipment.

Two videotape machines are currently in use. One is an Ampex Model VP-5900, one-inch helical scan unit which has been modified to allow random access and remote control. The second unit is an IVC (International Video Corporation) Model 800 CR, also a one-inch helical scan machine, which is originally equipped for random access and remote control. Operation of the two videotape units is accomplished under computer control through an interface hardware unit.

There is no provision for buffering the videotape programs. This means that any student station requiring a videotape segment demands the entire capacity of one videotape machine. Furthermore, access to any particular tape segment can require five or six minutes, in the worst case, although the average student wait is in the neighborhood of a minute and one-half. The slow response of an unbuffered video system imposes severe restrictions for which solutions are relatively expensive and generally unavailable with state-of-the-art equipment. These problems have been alleviated to some extent by duplicating tapes of instructional materials and using the two machines in parallel to service the four active student stations. In this way, the delays in servicing student requests are generally not cumulative. This solution cannot be recommended for a fully operational version of the educational system, but has proven satisfactory for studies designed to evaluate student reaction to, and use of, this particular type of educational medium.

5. Computer-Media Interface. The videotape and video disc resource center is integrated with the computer and student terminal group through a digital logic interface which was designed and constructed by project personnel. The interface is capable of connecting and driving as many as 32 independent media units and switching output to any one of 4096 student stations. The central computer delivers a request to the interface for a particular media device and a particular record in the device file, and specifies the location for delivery of the media output. Thereafter, the computer system proceeds on to its next functions and leaves the mechanics of media access and delivery to the interface unit. A complete technical description of the interface is available in a report by O'Neil.[4]

6. The Centralization Concept. A consistent effort has been made, in the design of this system, to centralize all media sources. Moreover, the decision to share a central computer with other users was intentional. Fundamental to these choices was the desire to take every possible opportunity to distribute capital costs of equipment over the widest possible user base. In this way, the educational system could employ the most sophisticated equipment available and still hope to hold costs within reasonable bounds.

The video memory disc provides the student with the most natural form of visual reinforcement and a single unit can service many learning stations. Since the unit can operate in a closely controlled environment, it is to be expected that operational reliability can be maintained at a high level and that routine maintenance can be minimized. The single file of imagery may be easily updated, for reasons of improving instruction, in a very short time and at negligible expense. Storage capability is large enough to accommodate the imagery requirements for a complete course and, since all imagery is available at any time, the system is not media-bound. This means that it is unnecessary to constrain the individual user to a particular subset of the educational materials, on any given day or hour, simply because the necessary media support cannot be coordinated.

There is difficulty in economic justification of the videotape system, even though centralization does help. The difficulty with the videotape arises for two reasons. First, presently available equipment cannot be driven fast enough in the random access mode; from one to five minutes are required to search out a particular tape segment. Second, the tape output cannot be buffered during play mode. This means that one machine is occupied for the entire time required for a student to see a particular tape segment. A particular machine is actually unavailable to more than one user for the total of access and play time. However, since a single unit would not be kept busy all of the time by any one student, centralization does allow sharing of the unit among a limited number of other students.

A centralized computer is common to most (if not all) computer based educational systems. However, the centralization concept is usually limited to mean that a single computer services all of the learning stations, but excludes all other uses of the machine. It was stated earlier that this project utilizes a computer in conjunction with a large number of other users who are engaged in the most common type of batch mode computation activity. The cost scaling principle is evident here. A highly sophisticated piece of equipment is made available to the specialized education function at marginal cost only. From the outset, the chief issue in attempting to take advantage of this situation was whether or not the interactive educational system could operate without intolerable response delays to the individual student. The present response level of the computer is averaging nine-tenths of a second and some improvement can be expected in the future. Such improvement may not prove worthwhile, however, as there is no clear evidence to show that the student would benefit from faster response.

Software

General composition and the system software is given in Table 2. Figures given for size of the various program components are somewhat dependent upon the number of student terminals utilized in the system and the specific set of instructional materials being presented. In particular, instructional program, communications dictionary and prepared text blocks will vary greatly for different instruction sets. The figures shown represent the requirements for a complete treatment of the subject of vector algebra.

An instructional program consists of a set of program modules; each module corresponds to a node point in the learning matrix (see Figure 1). The program module consists of a series of operators and operands written in an assembler language devised specifically for this purpose. For example, one program step may result in a message display on the CRT of a student station. This would be accomplished by writing: DISPLAY 243, where 243 is the record number of the desired message on the file of prepared text. The assembler presently in use provides for 30 operators which write messages contained in the text file, analyze student responses, activate the videotape and video disc equipment, perform program branching, etc. A typical program module

Table 2

Organization of Computer Programs for a Typical Instruction Set (Vector Algebra)

Program		Storage Requirement (60-bit words)
A.	Executor	6380_{10}
B.	Data Base	
	1. Student Records	7808
	2. Instructional Program	19456*
	3. Communications Dictionaries	4672*
	4. Prepared Text	89600*
C.	Auxiliary Support Programs	
	1. Computational Support	1300
	2. Games and Simulations	variable

*varies for each course of instruction

requires in the neighborhood of 30 computer words, the maximum allowable size being 120 computer words. In the more normal case where a student works completely through a program module, he may be engaged as much as 30 minutes, or as little as 2 minutes, by the coding for that module.

Flow through a program module is controlled by the executor, which also maintains student performance records, performs routine bookkeeping functions, processes the natural language strings from the student console and analyzes the individual student performance records to identify the next program module which fits the current requirement of the student. The executor also controls the flow of data to and from the mass memory devices of the computer system.

During normal operation of the system, any student can work with any of the program modules which the instructional package may contain, and a typical student will work with several of these during any one session. To accomplish this, 8330_{10} words of central memory are required on a continuous basis. Of this total, the executor requires 6380 words; 130 words are allocated to work space for each active student terminal (five terminals are currently provided for) and a 1300-word block is saved for use by any of the auxiliary support programs that may be attached to the specific subject package. During operation, the large volume of instructional programs, together with associated communications dictionaries and text, is stored in mass memory. A program module is loaded, as required, into the 130-word central memory work space that has been provided for each terminal. The central memory structure does not change with alterations to the program modules or as one course is substituted for another on the system; as additional terminals are added to the system, the central memory requirement increases by 130 words for each new terminal.

The executor program is constructed to allow on-line editing of any element contained in the instructional data base, including the instructional program modules.

Summary

A technology-based education model has been defined and discussed against a background of educational philosophy and methodology of implementation. The model consists of a set of terminal objective activities and a collection of learning resources which, for practical reasons, can receive treatment as a learning continuum only through technological methods. The system described is now an operational model which remains to be thoroughly evaluated. Through exposure to a wide variety of students, the system evaluation will concentrate on two main issues. The first and most important of these concerns the learning experience of the student population. The important observations will be:

a. whether or not the student can progress through the learning model;
b. how much time is required for the student to achieve the desired level of proficiency with the subject matter; and
c. student attitudes toward the system.

That the student can actually accomplish the prescribed terminal level activities is *a priori* evidence that the required learning has been accomplished. The second category of evaluation concerns performance data on the system itself. Questions to be answered relate to integrity of the design, long-term cost of operation and prospects for optimization and further generalization. □

Notes

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