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ABSTRACT

This report describes the development of an economically viable teaching system using a computer-based educational system. The PLATO system, used at the University of Illinois for the past nine years, is discussed. The authors report that by using newly-developed technological devices it is economically and technically feasible to develop large-scale computer-controlled teaching systems for handling 4000 teaching stations. The cost of instruction would be comparable to the cost of teaching in elementary schools. (Author/FL)

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THE DESIGN OF AN ECONOMICALLY VIABLE LARGE-SCALE COMPUTER BASED EDUCATION SYSTEM

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The Design of an Economically Viable Large-Scale Computer-based Education System*

by

D. Bitzer and D. Skaperdas

Computer-based Education Research Laboratory †

The University of Illinois has been experimenting with a computer-based educational system (PLATO) for the past eight years. This system has evolved from a single terminal connected to the ILLIAC I (a medium speed, 1954 vintage computer) to a computer classroom of 20 graphic-pictorail terminals connected to a Control Data Corporation 1604 computer. Some of the areas in which studies have been conducted are electrical engineering , geometry, biology, nursing, library science, pharmacology, chemistry, algebra, math drill, computer programming, and foreign languages. This material has been presented by use of a variety of teaching strategies, ranging from dirll and practice to student-directed inquiry. Based on these experiences and the data gathered over 70,000 student

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contact hours of credit teaching, this report describes the development of an economically viable teaching system. Some of our guidelines for developing the system's software and hardware are:

1) The computer should only be used when it is the best method of presentation. Less expensive methods such as programmed texts, films, slides, tape recorders, etc., should be used when appropriate.

2) The computer should be used as much as possible to simulate results in models constructed by the students rather than simply turning pages.

3) The system must be flexible and adaptable. It must be able to teach many subjects and present the lesson materials by a variety of teaching strategies. The system must change to meet the needs of the students and teachers, and not be limited to the off-the-shelf items presently available.

4) The method of integration into the educational system must be considered in the system design. For example, a school should be able to start with a single terminal for the incremental terminal cost instead of having to invest large sums of money for an entire system before the school has determined if it wants or needs C.B.E.

5) The cost of computer-based education should be comparable with the cost of teaching at the elementary grade school level. Cost effectiveness should be determined by an hour to hour cost comparison (25¢-30¢ per terminal hour for use of the computer and terminal).

A present student terminal consists of a keyset and a television monitor as shown in Fig. 1. Information viewed on the television monitor is composed of a slide selected by the computer (randon-access time less than 1 millionth of a second) and a superimposed image of graphs, diagrams, and/or alphanumeric characters drawn by the computer in a point-by-point fashion. The student uses the keyset for constructing answers, questions and for setting up simulated or real experiments as well as for controlling his progress through the lesson material. The computer responds to the student's requests within one tenth of a second.

The computer also controls other devices, such as movie projectors, lights, etc. The students at the terminals can interact with each other through the computer, thus permitting games to be played which require communication between the players.

In addition to keeping detailed records of the student's performance, the computer can provide individualized instruction, immediate feedback, and remedial training by the use of complex internal branching and the alteration of presentation or type of material based on the student's past performance. These unique features seem to make the computer an ideal instructional device for developing cognitive skills.

To encourage development of critical thinking skills, the author sets up the teaching strategy and presents the student with questions or problems so the student must think about what information he needs, about possible solutions to the problems or sources of information, interpret the data gathered, and test his solution. The computer immediately provides appropriate feedback to open-ended questions, thus reinforcing a correct approach, or in the case of an incorrect response, encouraging the student to a new approach.

The computational use of the computer appears in several ways. First, experiments can be simulated by the computer, immediately providing the student with results he uniquely requested. These same results might require hours or even days to calculate by hand. Second, a large amount of computation is involved in processing student responses. The more flexibility provided for the student to answer a question, the more feedback is needed to inform him of the correctness of his response. When only multiple-choice responses are required, the processing is relatively simple, but when the student is permitted to construct long alphanumeric and graphic responses the computer must analyze his answer to see if it is equivalent to a correct response, check for spelling and completeness of the answer, as well as inform him which part of an incorrect answer is unacceptable.

Whenever possible, algorithms are used to determine the correctness of the students' response. For example, when the student is asked to give a positive even integer, the student's answer is checked to see if it is positive and then it is divided by two and checked for a remainder. If there is no remainder, the answer is correct. The use of algorithms instead of comparing the answer against a long list of pre-stored answers not only makes the system more flexible but also saves memory space. In some cases this approach is almost a necessity. For instance, in teaching algebraic proofs, students can prove theorems in any manner as long as their statements follow logically from the available axioms and their previous statements. We have one example in which the author of the material was unable to prove a theorem in the twelve lines provided and, thus, was unable to supply even one pre-stored solution. Nonetheless, one student was able to complete the proof in the required twelve lines and was told by the computer he was correct.

To illustrate further how the computer interacts with the student we will describe some sequences taken from lessons in geometry, electrical engineering, and maternity nursing.

A user's computer language consisting of English directives was used to write a series of 15 lessons in informal geometry.* These lessons were to give 7th and 8th grade students an understanding of geometric concepts. A grid is provided on which the student draws and manipulates geometric figures. The computer is used to determine the correctness of the figure, independent of its size, location, and orientation on the grid. The student must select points of the grid to be used as the vertices of his figure. To do this, eight keys on his keyset have been defined which move a bright spot around on the grid. (Figure 2 shows a diagram of these keys. The arrows on the keycaps indicate the direction in which the key jumps the bright spot on the grid.) Once a student has decided on a point, he communicates his selection to the computer by pressing the "MARK" key. He presses the "CLOSE" key to close the figure (connect the first point to the last point). To judge the figure the student presses "NEXT" and the computer either okays the figure or indicates the student's error.

In the following sequence, the student is asked to draw quadrilaterals with a single line of symmetry. In Fig. 3a the student is instructed to draw a quadrilateral with one line of symmetry: the two possibilities are an isosceles trapezoid and a kite. He selects the points he wishes to use for his figure and marks them. Fig. 3b shows the partial construction of the trapezoid. When four points have been marked the student closes his figure and asks the computer to judge it. In Fig. 3c the completed figure is judged and the computer points out to the student that the symmetry line for an isosceles trapezoid does not go through the vertices.

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The student then moves to the next page of the lesson and is asked to draw a quadrilateral with a single line of symmetry that does go through the vertices (Fig. 3d). The student, however, reconstructs the trapezoid. The computer, when judging the figure, recognizes the duplication and tells the student that he has drawn the same figure as he drew before (Fig. 3e). The student then draws a kite which has a single line of symmetry through vertices and the figure is judged "OK" (Fig. 3f).

For our second case we use a sequence taken from a circuit analysis course in electrical engineering (Fig. 4). The student has just analyzed a circuit containing a battery, a switch, an inductor, and a resistor, all connected in series. His task is to determine the value of the inductor and resistor that causes the current waveform to pass through the points marked on the graph after the switch is closed. He is instructed to make the resistor value small and notice the effect on the final value of the current. By manipulating these values, the student gains an intuitive feeling for the effects of the inductance and resistance, and he can proceed in an orderly way to determine their correct values.

The third example is taken from a maternity nursing lesson* where the student is presented with a question which asks her to list two cardiovascular compensations which occur as a result of the increased blood volume during pregnancy (Fig. 5).

The student, needing information to answer this question, presses the button on her keyset labeled "INVEST". She is then presented with a slide where she indicates that she wishes to investigate "Anatomic and Physiological Changes of Pregnancy".

* This project is supported by PHS Training Grant No. NPG 188, Division of Nursing, PHS, U.S. Dept. of Health, Education and Welfare.

After choosing her area of investigation, she is presented with a slide which requests further specification. Here the student indicates that she wishes information concerning changes which occur in the circulatory system during the third trimester of pregnancy. Having done this, she presses the "Answer" button and the computer generated information tells her there is an "increase in blood volume, a 50 percent increase in cardiac work load, left ventricular hypertrophy, and vasodilation produced by an increase in progesterone". Deciding that increased work load is one compensation, she considers left ventricular hypertrophy, but needs to further clarify the word hypertrophy. By pressing the button labeled DICTIONARY, she is presented with a list of terms used in the lesson. The student types the word "hypertrophy" and the computer supplies the definition "increase in size of an organ or structure".

By pressing the button labeled "AHA", the student is returned to the question on which she was working. Here she types the answer "hypertrophy of the left ventricle" and the computer judges it "OK". However, the answer "the left ventricle" is judged NC, that is, correct but not complete. Rewording the correct answer, the student types "the left ventricle enlarges" and the computer responds "OK". However, when the student presses the "CONTINUE" button to advance to the next page, the computer prints out "Duplicate Answer". Next, the response "the left ventricle decreases in size" is entered. The computer responds "NO" and XX's out the word "decreases". Before the student can continue, she must change one of her responses to a correct answer which differs from the first.

Records of each student's request (his identity, the key pushed, and the time to the nearest sixtieth of a second)is stored on magnetic tape. These data are processed by the same computer that is used for teaching. We have used these records for improving course content, designing better teaching strategies, as well as for planning new, economically viable computer-based education systems.

On the basis of CERL's experience with early PLATO systems, certain design philosophies for the proposed system have been formulated. First, each student terminal requires a keyset and a display, both connected to an inexpensive data transmission system which can also drive optional equipment such as random-access audio devices, reward mechanisms, movie films, lights, and so forth. Second, each student terminal must be capable of superimposing randomly-accessed color slide images on the computer-generated graphics. Third, the system should be controlled by a large-scale centrally-located computer rather than many small computers located at the classroom sites. This decision is based upon social and administrative factors as well as on system economics. Semiconductor large-scale integration techniques may some day make the use of small computers as effective as large ones, but the added human expense of operating a computer center does not promise to scale as effectively. It is our opinion that the initial low cost of a single terminal will permit tightly-budgeted public schools systems to economically incorporate computer-based teaching into their programs. The number of terminals could be increased or decreased as the needs of the school system dictate. Fourth, the cost per student contact hour for the proposed system must be comparable with equivalent costs of traditional teaching methods.

Before discussing an economical system design from the technical viewpoint, it is necessary to consider the cost of producing lesson material.

Reported costs have ranged over a factor of 10 for producing similar lesson material. The differences in author languages can account for this wide range. The author language must be just as natural for the teacher to use as the teaching strategy is expected to be natural for the student to use. However, in the long run, the cost of lesson material should constitute only a small fraction of the educational costs just as the textbooks and lesson materials represent only a small part of educational costs today.

Preparing a good CAI course is roughly equivalent in effort to writing a good textbook. Most good authors are quite willing to produce textbooks at a 10-15% royalty rate which yields to them approximately 80¢ per student. Most textbooks are used in courses which have at least 40 hours of classroom instruction. The cost of royalties, reproduction and distribution of lesson material total to $1.20 per student, and when used for 40 hours of instruction yields an eventual cost of approximately 3¢ per student hour of instruction. The reproduction and distribution of materials for computer-assisted instruction terminals promises to be very inexpensive (approximately 40¢ per student for visual and audio materials).

Statistical records of over 70 million requests on PLATO indicate that the average request rate per student depends upon the teaching strategy used, but the product of the average request rate and the average processing time is relatively constant. For example, when using a drill-type teaching strategy the average request rate per student is one request every 2 seconds and the average processing is 10 milliseconds. When using a tutorial or inquiry strategy, the average request rate per student is one request every 4 seconds but the processing time is 20 milliseconds. We will base our calculations on the 20 millisecond processing time which is equivalent to executing approximately 1000 instructions in the CDC 1604.

The request rate probability density function versus computer execution time is approximately an exponential curve; therefore, student requests requiring the least amount of computer time occur most frequently. For example, the simple and rapidly-processed task of storing a student's keypush in the computer and writing the character on his screen represents 70 percent of the requests. On the other hand, the lengthy process of judging a student's completed answer for correctness, completeness, spelling, etc., occurs only 7 percent of the time.

Several existing large-scale computers can perform about 4×10^6 instructions per second. Even if we double the number of instructions needed, providing 2000 per student request, it is seen that these large-scale computers require an average processing time of only 500 microseconds per request. Allowing a safety factor of two to insure excellent system response time, the system can accept an average of 1000 requests per second. This safety factor implies that the computer will be idle approximately 50 percent of the time. However, the computer time not utilized in processing the student requests can be effectively used for other purposes such as background batch processing. Since the average student request rate is 1/4 of a request per second, the system can handle up to 4000 students simultaneously, allowing one millisecond to process a request.

Assume that the student input arrival time is Poisson distributed (a reasonable assumption for 4000 independent student stations), and that the request rate probability density function versus computer execution time is approximately exponential (PLATO statistical records substantiate this).

From queuing theory [2,7] the expected waiting time E(w) that elapses before the computer (single channel) will accept a given student's request is given by

$$E(w) = \frac{\rho^2 + m\,\sigma_t^2}{2m\,(1-\rho)} \qquad (1)$$

where

m = request rate = 1,000 request/sec.,

σ_t = execution time standard deviation = 500×10^{-6} sec.,

$E(t)$ = execution time expected value = 500×10^{-6} sec.,

$\rho = mE(T) = 0.5$

These values yield an expected waiting time E(w) of 500 mocroseconds. The probability P(w) that a student's request will wait a time w or longer before being served by the computer is given by

$$P(w) = \rho \exp\left[-w\,(1-\rho)/E(T)\right] \qquad (2)$$

The probability that a student must wait for a 0.1 second or longer is negligible. Hence the probability of a student's request queue becoming long, or of the student experiencing a noticeable delay is very small.

Presently, each student needs to be assigned approximately 300 words of extended core memory to be treated individually. The maximum used in any teaching strategy has been 600 words per student. Let us allow on the average 500 words (fifty bit) for each student for a total of 2×10^6 words for 4000 student terminals. Our data shows that 20 percent of the computer instructions refer to these words of unique student storage. Therefore, the system must be capable of rapidly transferring data between the slower extended core storage and the high-speed core memory. Some existing computers are capable fo transferring data at 10^7 words per second, requiring only 50 microseconds to transfer the data each way between the memory units.

This transfer time is acceptable.

The peak data rate from the computer to each student station is limited to 1200 bits per second to permit data transmission over low-grade telephone circuits, a system feature made possible by the use of the plasma display panel discussed later. For 4000 stations the worst case data rate would be about 4.8 million bits per second, well within the present state of the art for buffering data out of a computer.

Summarizing the computer requirements, therefore, the central computer requires about 2 million words of extended core memory capable of high-speed transfer rates to the main computer memory, it must have an execution time of approximately 4 instructions per microsecond and be capable of transmitting data at a rate of 4.8 million bits per second. There should be a sufficiently large memory (64k to 128k words) in the central processing unit for storing lessons (1k to 2k words per lesson) and for the various teaching strategies. Several existing computers meet these requirements.

The economic feasibility of the proposed teaching system is dependent upon the newly-invented plasma display panel (or equivalent device) now under development at the University of Illinois and other laboratories. This device combines the properties of memory, display and high brightness in a simple structure of potentially inexpensive fabrication. In contrast to the commonly-used cathode ray tube display, on which images must be continually regenerated, the plasma display retains its own images and responds directly to the digital signals from the computer. This feature will reduce considerably the cost of communication distribution lines.
The plasma display is discussed in detail in the listed references. Briefly, it consists of a thin glass panel structure containing a retangular array

of small gas cells (about .015 inches density of about 40 cells per inch--see Fig. 6). Any cell can be selectively ignited (gas discharge turned on or turned off by proper application of voltages to the orthogonal grid structures without influencing the state of the remaining cells). Fig. 7 shows a small, developmental panel displaying two characters. Each of these characters is only one-eighth inch in height. The plasma panel is transparent, allowing the superposition of optically projected images.

A schematic of a proposed student terminal using the plasma display is shown in Fig. 8. The display will be approximately 12 inches square and will contain 512 digitally addressable positions along each axis. A slide selector and projector will allow prestored (static) information to be projected on the rear of the glass panel display. This permits the stored information to be superimposed on the panel which contains the computer-generated (dynamic) information. A prototype random-access slide selector for individual use is shown in Fig. 9. This projector is digitally addressable, pneumatically driven, and contains a matrix of 256 images on an easily removeable four-inch square plate of film. The film plate is mounted on a Cartesian-coordinate slide mechanism and can be simultaneously translated along either of the two coordinate axes to bring a desired image over a projector lens. The positions along each coordinate axis are selected by a set of four pneumatic cylinders mounted in series. The stroke length of each cylinder is weighted 8,4,2,1, the length of the smallest being 1/4 inch. Each slide selection requires less than three cubic inches of air at 8 psi. Based upon the prototype model now being tested, a low-cost image selector with approximately 0.2 second random-access time is anticipated.

Data arriving from the computer via a telephone line enteres the terminal through an input register. As previously stated, data rates to the terminal will be held to 1200 bits per second. Assuming a word length of 20 bits, the terminal could receive data at 60 words per second, an important design feature when considering standard TV tariff for communicating. With proper data formats, data rates will be adequate for the applications envisaged. For example, packing three character codes per word will permit a writing rate of 180 characters per second, which is a much faster rate than that of a good reader. Using 18 bits to specify a random point on the 512x512 array, 60 random points per second can be plotted. If the x increment is assumed such as when drawing graphs, 120 graph points per second can be plotted. In addition, continuous curves requiring only 3 bits to specify the next point can be drawn at rates of 360 points per second. The keyset will provide the student with a means of communicating with the computer. The problem of converting the fast parallel output data from the computer into serial data for transmission to terminals at 1200 bits/sec. has been studied. This can be solved by the use of small size buffer computers performing the parallel-to-serial data conversion.

In the situation where a large number of students are located at considerable distances from the central computer, costs can be lowered drastically by use of a coaxial line instead of numerous phone lines. For example, the cost of a 4.5 MHz TV channel is approximately $35 per month per mile, whereas the rate for a 3kc telephone line is approximately $3.50

per month per mile. Each TV channel can handle at least 1500 terminals on a time-shared basis, each terminal receiving 1200 bits per second. Hence, for an increase in line cost of a factor of 10 over that of a single channel, an increase of a factor of 1500 in channel capacity can be obtained. In addition to a coaxial line transmitting 1500 channels at 1200 bits per second from the computer to the terminals, a data line for transmitting the student keyset information back to the main computer center is required. A data channel of 100,000 bits/second capacity, available from Bell Telephone can handle 1500 students, allowing 60 bits/second to each student. The costs for this line are approximately $15 per month per mile. Data to remote locations will be transmitted by a coaxial line to a central point; from this point local telephone lines rented on a subscriber's service basis would transmit the proper channel to each student terminal. A block diagram of a proposed distribution system to several remote points is shown in Fig. 10.

Over 200 cities, and on a more limited scale many schools, already use community antenna television systems or closed-circuit TV. Because FM radio had already established itself prior to the spread of television, a frequency gap existed between channels 5 and 6 which is almost 8 channels wide. These existing channels can be used to communicate to over 12,000 home terminals.

The mainframe cost of a computer meeting the specified requirements is approximately 2.5 million dollars. The additional cost for two million words of memory and other input-output equipment is approximately 2 million dollars. An estimate for the system software, including some course development programming, is another 1.5 million dollars. The total of 6 million dollars amortized over the generally-accepted period of 5 years yields 1.2 million dollars per year.

Assuming that the 4000-terminal system will be in use 8 hours a day for 300 days a year, there are approximately 10 million student contact hours per year. The system costs, excluding the terminals, is thus 12¢ per student contact hour. In order for the equipment cost to be comparable to a conventional elementary school classroom cost of approximately 27¢ per student contact hour, the terminal costs must be limited to 15¢ per student contact hour, or to a total cost of about 7.5 million dollars over a 5 year period. The cost for each of the 4,000 terminals, which included a digitally-addressed graphical display device and its driver, a keyset, and a slide selector must therefore be a maximum of approximately $1900. Present indications are that this cost can be met.

Data distribution costs for a CBE center approximately 100 miles from the main computer are approximated as follows. The coaxial line rental is approximately $350[illegible] per month, or $2.35 per terminal per month, based on 1500 terminals. The 1[illegible]0,[illegible]0 bit/second wide-band data channel line is approximately $1500 per month, or $1.00 per terminal per month. Allowing $3.00 per terminal per month for a private telephone line from the coaxial terminals to each student terminal gives a total data distribution cost of $6.35 per terminal per month, or 4¢ per student contact hour if each terminal is used 160 hours per month. The author costs were discussed previously.

These costs, based on the above assumptions, are summarized in Chart I. The earning power of the computer for the remaining 16 hours each day and for the idle time between student requests, which would further reduce costs, has not been included.

Conclusion

Using newly-developed technological devices it is economically and technically feasible to develop large-scale computer-controlled teaching systems for handling 4000 teaching stations which are comparable with the cost of teaching in elementary schools. The teaching versatility of a large-scale computer is nearly limitless. Even while simultaneously teaching 4000 students, the computer can take advantage of the 50 percent idle time to perform data processing at half its normal speed. In addition, 16 hours per day of computer time is available for normal computer use. The approximate computer cost of 12¢ per student contact hour pays completely for the computer even though it utilizes only 1/6 of its computational capacity. The remaining 5/6 of its capacity is available at no cost.

Table 1

SUMMARY OF COSTS

Item	Total Cost in millions of dollars	Cost/year in millions of dollars 5 years Amortization	Cost per student contact hour
Computer and extended memory	4.5	0.9	8¢
Software	1.5	0.3	4¢
4000 student terminals	7.5	1.5	15¢
Subtotal	13.5	2.7	27¢
Lesson material	-----	-----	3¢
Data distribution lines	-----	-----	4¢
TOTAL			34¢

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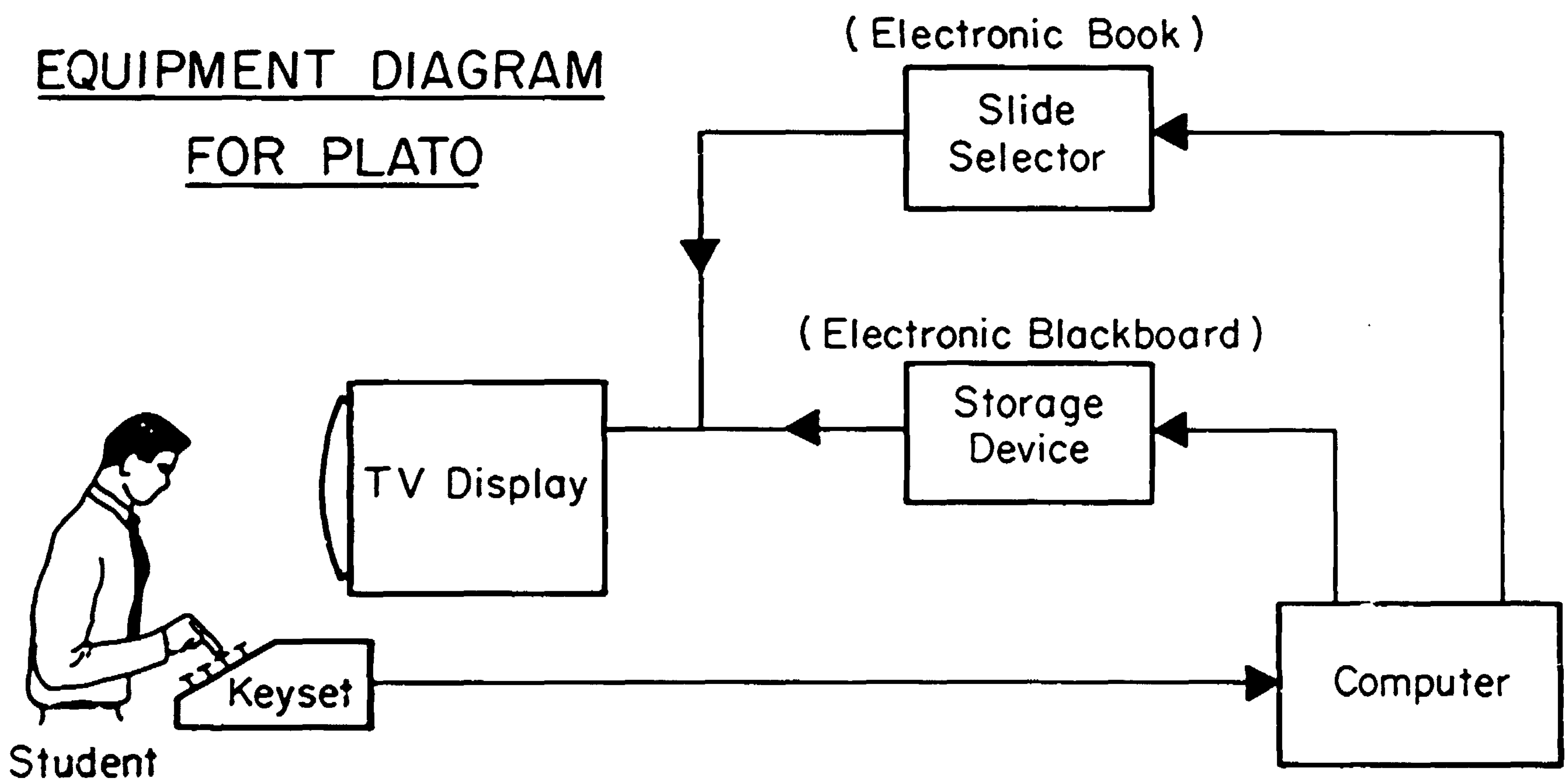

EQUIPMENT DIAGRAM
FOR PLATO
(Electronic Book)
Slide Selector
(Electronic Blackboard)
Storage Device
TV Display
Computer
Keyset
Student

FIGURE 1

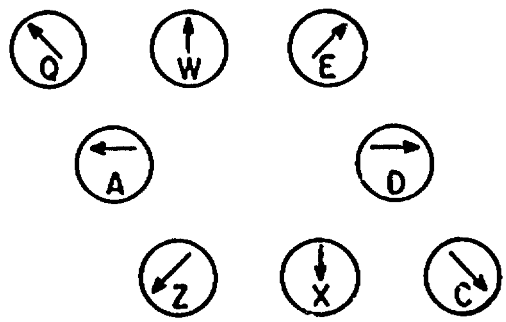


FIGURE 2

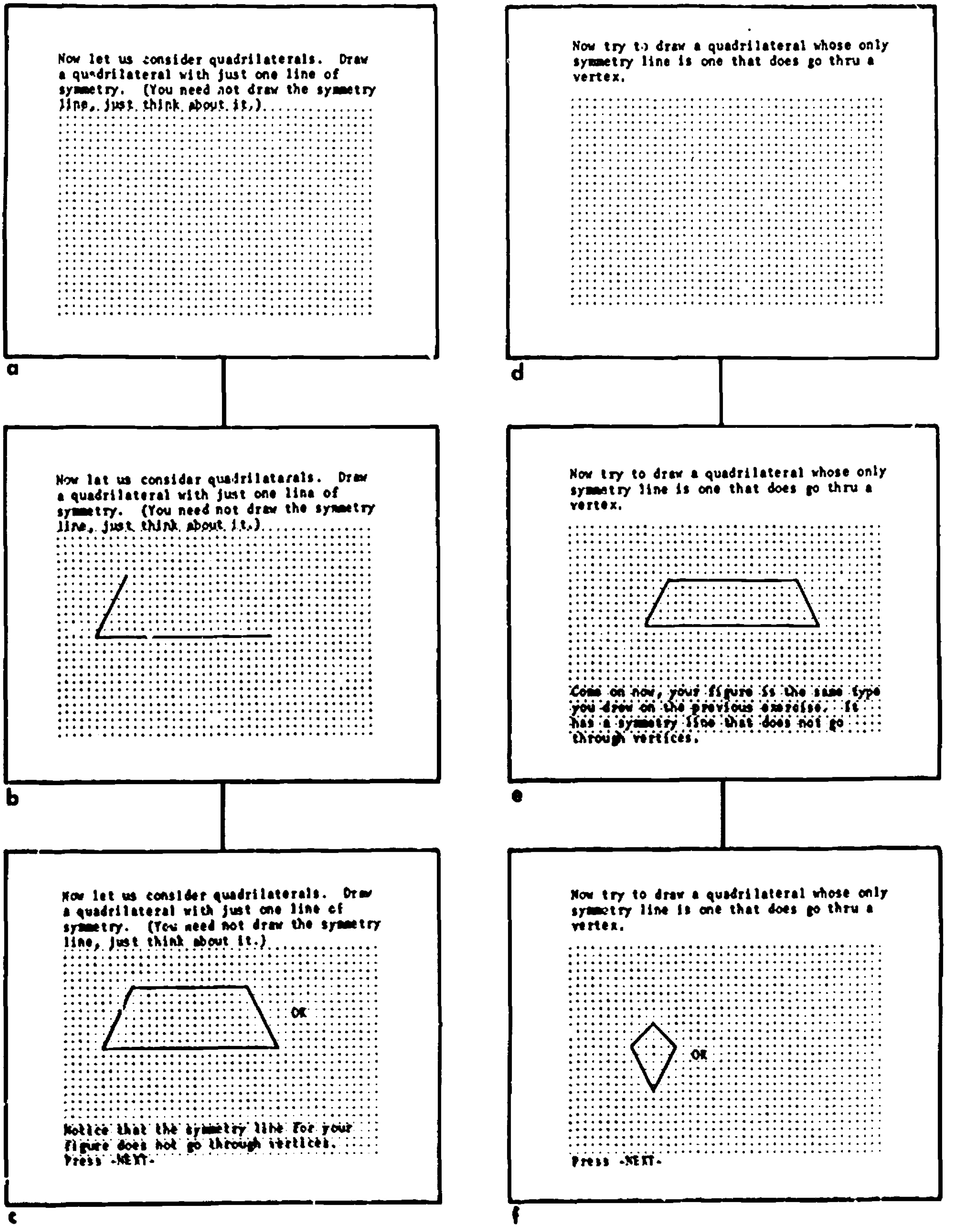


Fig. 2 An Example From a Geometry Lesson

FIGURE 3

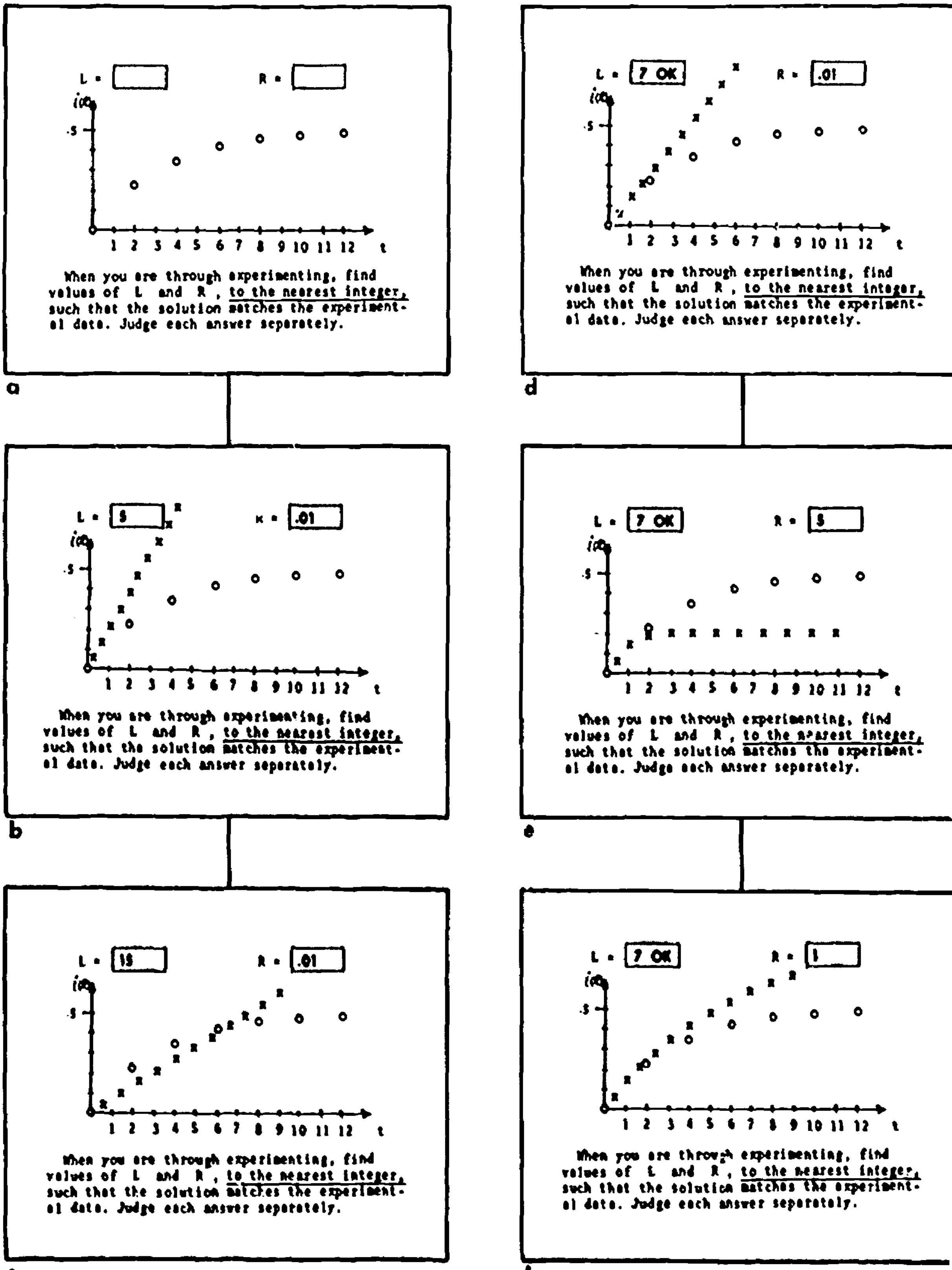
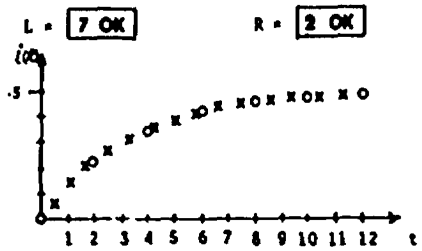

L =
R =
.5
1 2 3 4 5 6 7 8 9 10 11 12 t
When you are through experimenting, find values of L and R, to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.
a
L = 5
R = .01
b
L = 15
R = .01
c
L = 7 OK
R = .01
d
L = 7 OK
R = 5
e
L = 7 OK
R = 1
f

FIGURE 4



When you are through experimenting, find values of L and R, to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

9

FIGURE 4 (Cont.)

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.

2.

a

INVESTIGATE

Indicate area of investigation desired:

1

1. Anatomical and physiological changes of pregnancy
2. Nursing strategies
3. Prenatal records

Push ANS

b

Investigation Now in Progress

Type name of part desired: CIRCULATORY SYSTEM

(for listing of acceptable requests see DATA)

Indicate trimester of pregnancy: 3

(use 1, 2, or 3)

Push ANS

c

Circulatory System

↑ in blood volume, 50% increase in cardiac work load. Left ventricular hypertrophy. ↑ progesterone produces vasodilation. Pressure from enlarging uterus slows return venous circulation.

d

Dictionary Page 2

hematocrit	orifice	stasis
hemoglobin	os	symphysis pubis
hemorrhoids	papilla	thoracic
hyperplasia	perineum	transient
hypertrophy	physiologic	trimester
labia	predisposition	urethra
lactiferous	preeclampsia	varicosities
LMP	prenatal	vasodilatation
micturation	promontory	VDRL
myometrium	pseudoanemia	vital capacity
Nageles rule	pyelonephritis	xiphoid

Type word to be defined:

Press ANS HYPERTROPHY

e

Dictionary Page 2

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LMP	prenatal	vasodilatation
micturation	promontory	VDRL
myometrium	pseudoanemia	vital capacity
Nageles rule	pyelonephritis	xiphoid

Type word to be defined:

Press ANS HYPERTROPHY

INCREASE IN SIZE OF AN ORGAN OR STRUCTURE

f

FIGURE 5

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.

g

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE NO

h

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE ENLARGES OK

i

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE ENLARGES OK

DUPLICATE ANSWER

j

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE DECREASES IN SIZE

k

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE [redacted] IN SIZE NO

l

FIGURE 5 (Cont.)

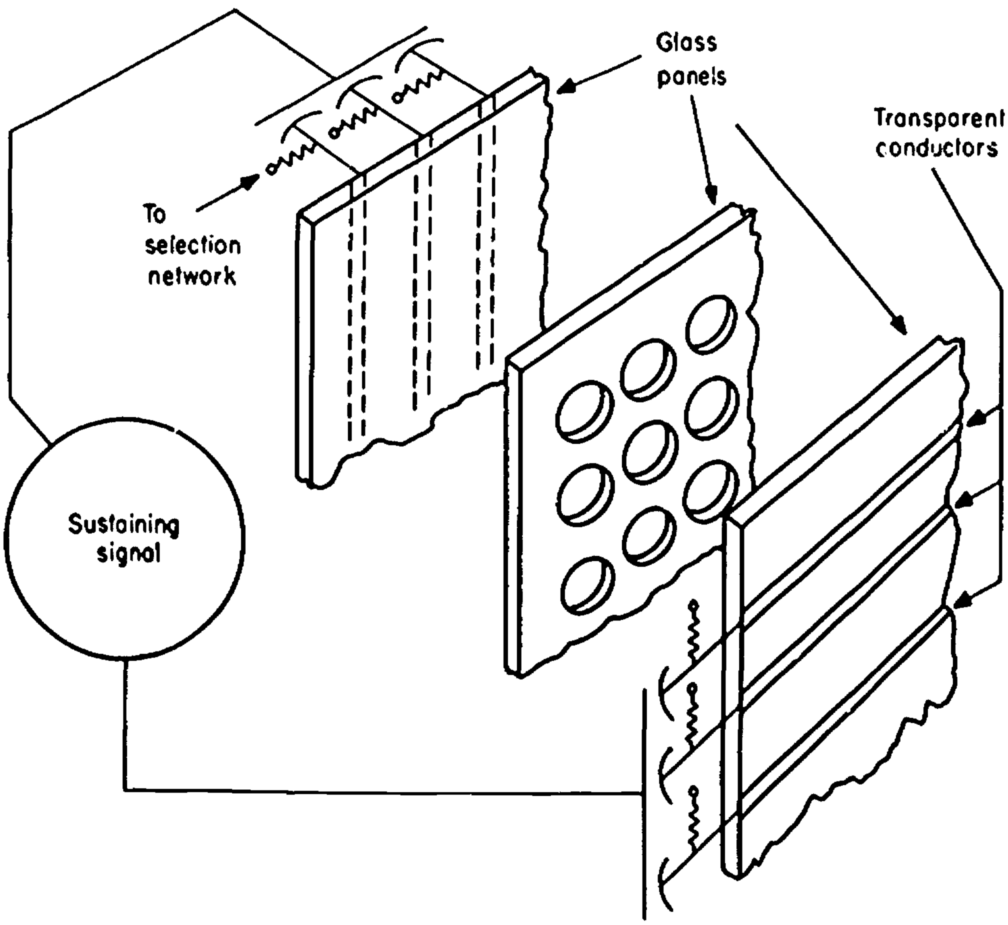
Glass panels
Transparent conductors
To selection network
Sustaining signal

FIGURE 6

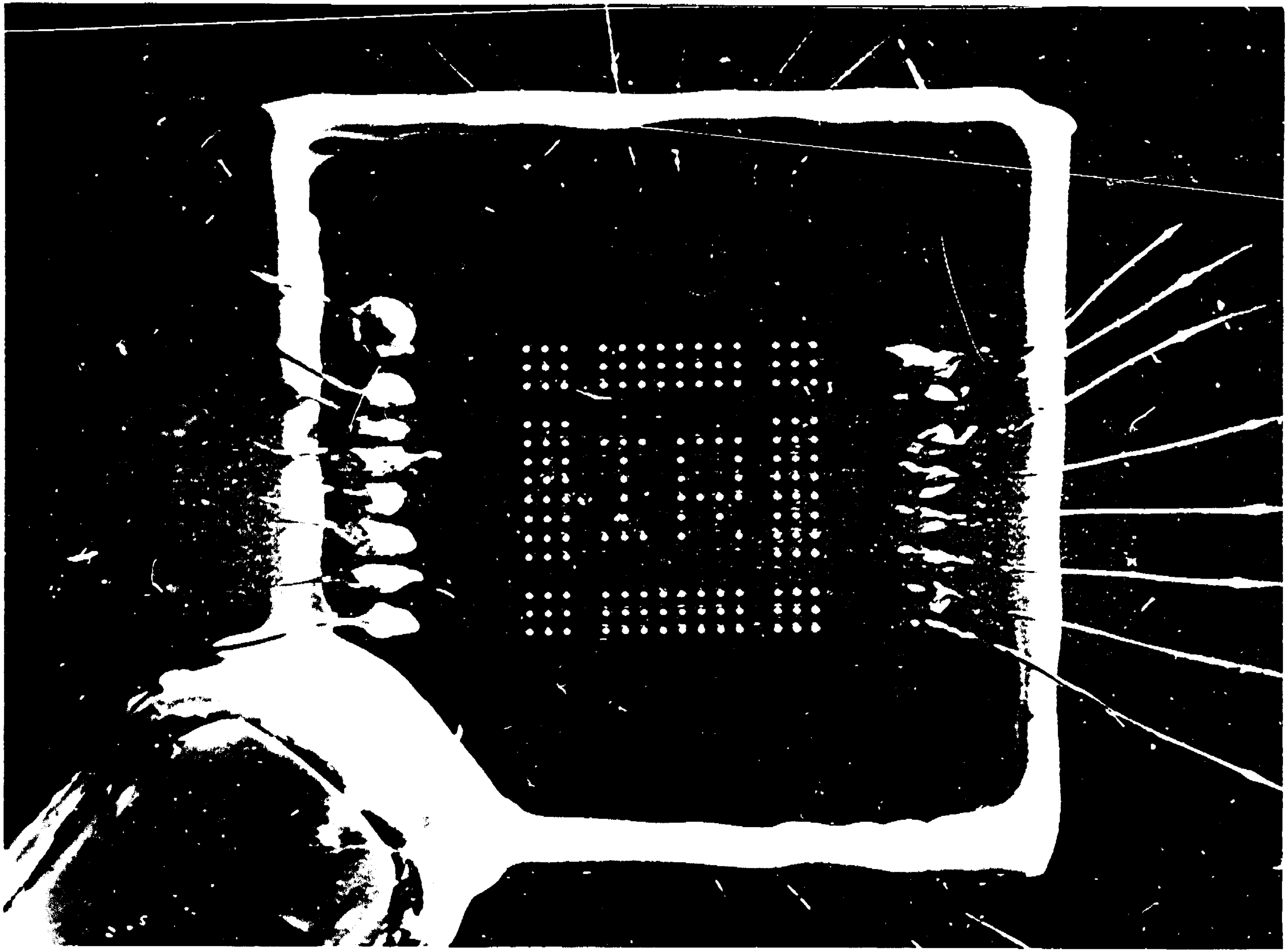

FIGURE 7

STUDENT TERMINAL

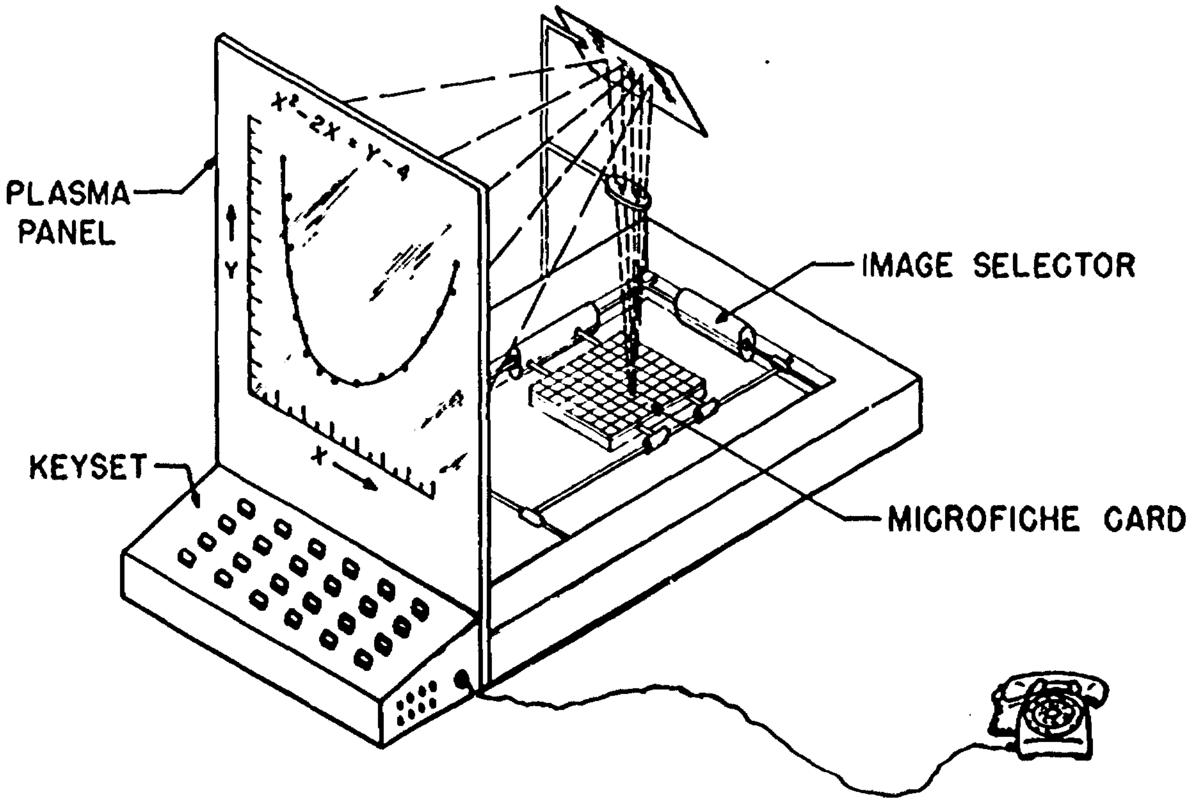

FIGURE 8

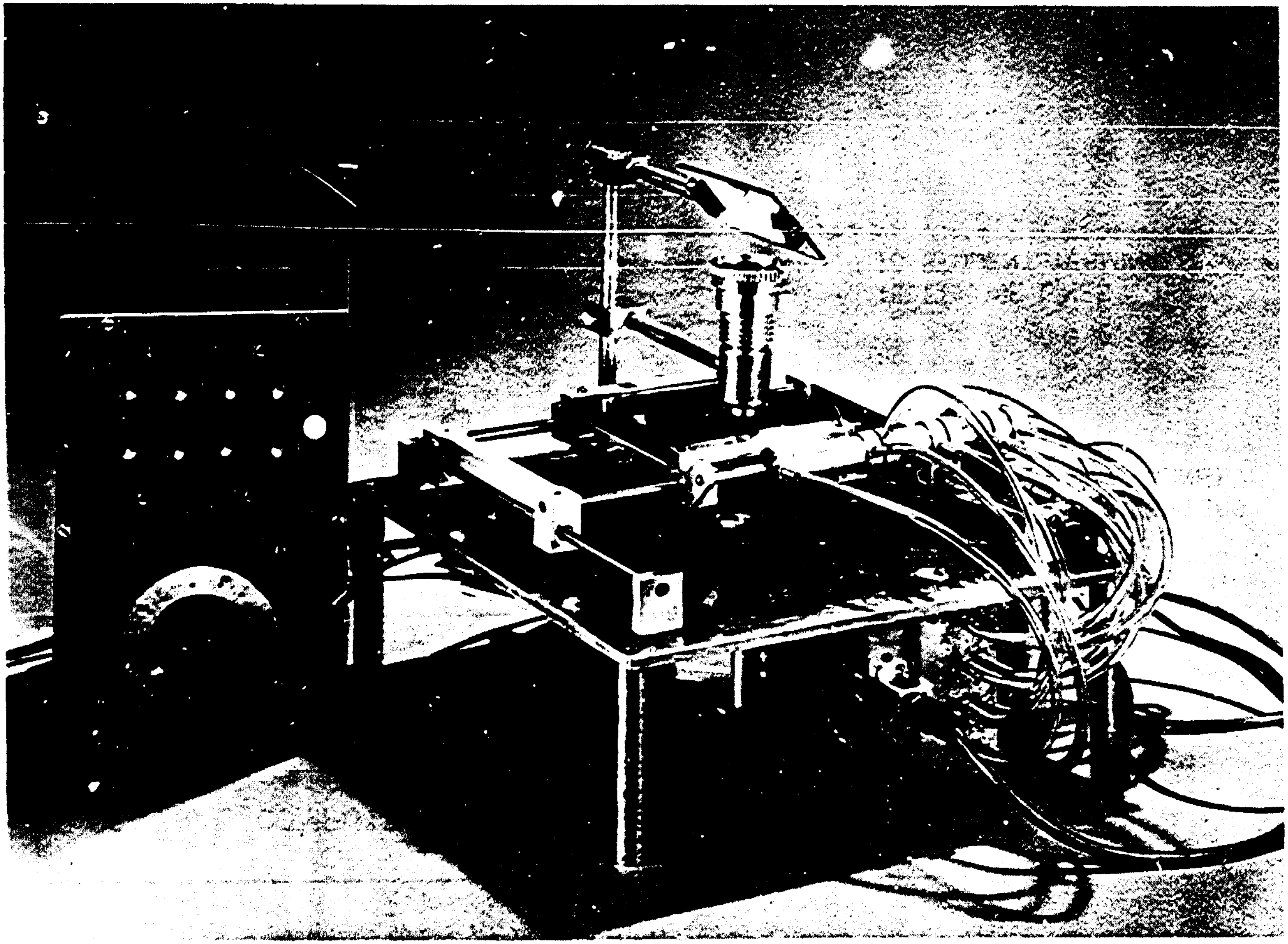

FIGURE 9

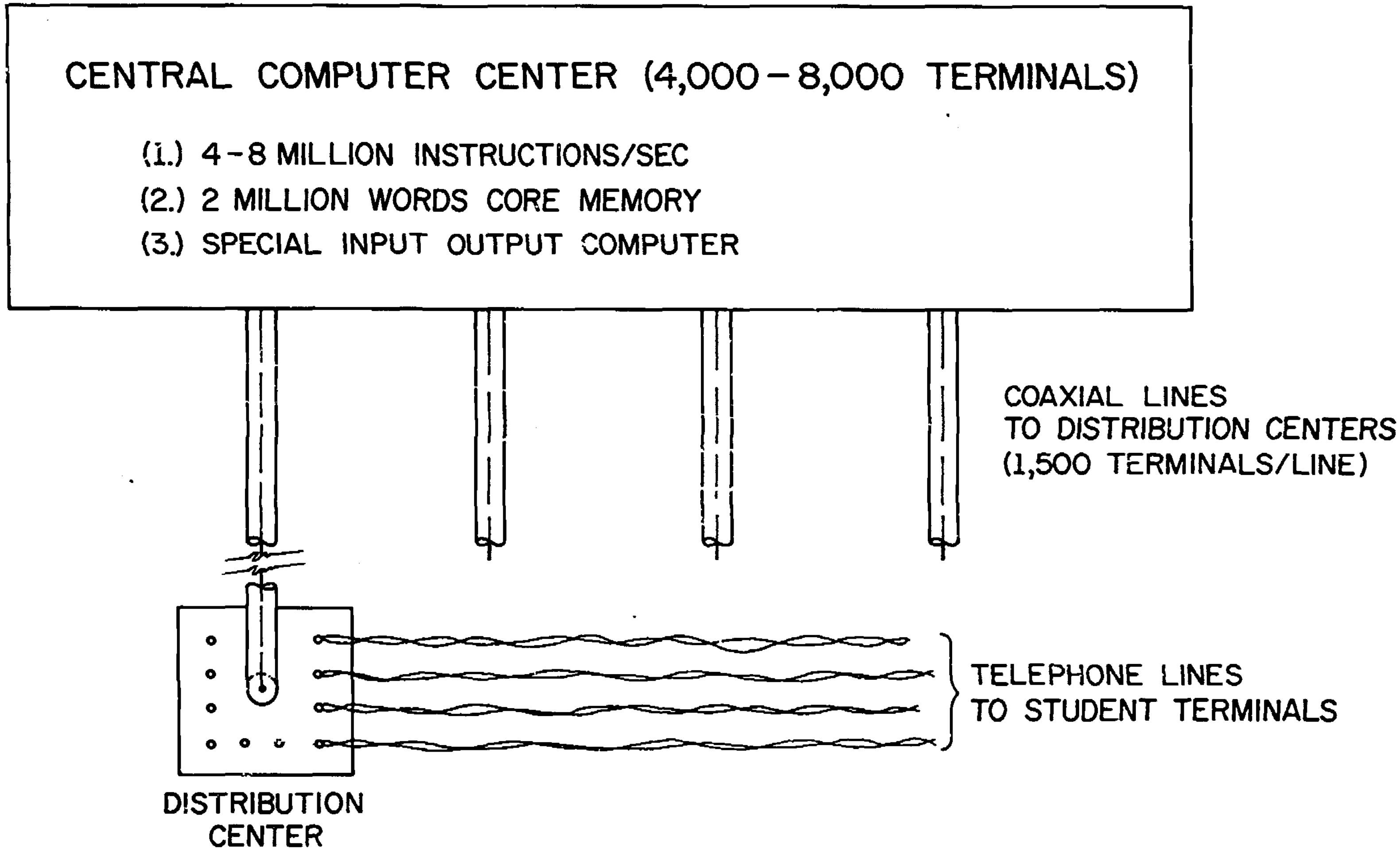
CENTRAL COMPUTER CENTER (4,000 – 8,000 TERMINALS)
(1.) 4 – 8 MILLION INSTRUCTIONS/SEC
(2.) 2 MILLION WORDS CORE MEMORY
(3.) SPECIAL INPUT OUTPUT COMPUTER
COAXIAL LINES
TO DISTRIBUTION CENTERS
(1,500 TERMINALS/LINE)
TELEPHONE LINES
TO STUDENT TERMINALS
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FIGURE 10

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13. ABSTRACT

The University of Illinois has been experimenting with a computer-based educational system (PLATO) for the past eight years. The system has evolved from a single terminal connected to the ILLIAC I (a medium speed, 1954 vintage computer) to a computer classroom of 20 graphic-pictorial terminals connected to a Control Data Corporation 1604 computer. Using newly-developed technological devices it is economically and technically feasible to develop large-scale computer-controlled teaching systems for handling 4000 teaching stations (PLATO IV) which are comparable with the cost of teaching in elementary schools. The teaching versatility of a large-scale computer is nearly limitless.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Computer-assisted Instruction						
Computer-based Instruction						
PLATO						
PLATO IV						
Lesson Sequences						
Geometry						
Electrical Engineering						
Maternity Nursing						
System Economics						
Economical System Design						
Plasma Display Panel						
Student Terminal						
4000 Terminal System						
Data Distribution Cost						