AD 658476

SP-2909/000/01

Applications of Computers in Education

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29 August 1967

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$\mathbb{SP}$ *a professional paper*

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by

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August 29, 1967

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Paper presented at the American Management
Association Conference, Americana Hotel,
New York, August 9, 1967.

ABSTRACT

Four areas of computer applications to education are described: (1) the computer
as a subject of instruction; (2) as a tool of instruction; (3) as a research and
development tool; and (4) as a management tool. These applications are viewed in
the context of an operational time-sharing system connecting many schools with a
central computer. Three problem areas in implementing such a system are discussed:
(1) man-machine communication; (2) cost-effectiveness; and (3) user acceptance.

Applications of Computers in Education

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I. COMPUTER APPLICATIONS IN EDUCATION

The Computer as a Subject of Instruction

Society is undergoing rapid change as the result of computer technology. Our institutions, values, and habits of work and leisure will be different for students by the time they graduate. To expose students to the environment in which they will be living, we must include in their education the cultural and technological aspects of computers. Computer literacy is essential if the problems that will be presented by an automated society are to be solved. With the growing demand for computer specialists alone, it is not unreasonable to assume that computer technology will become an integral part of the secondary school curriculum in the next five years.

At System Development Corporation (SDC), we have taught computer programming to junior high school students by means of a special computer language called TINT (Teletype INTerpreter). The TINT program was designed to function as an interpreter between the digital computer and a user operating a teletype terminal. TINT has special tutorial and error-checking capabilities that enable the non-programmer student to perform a wide variety of information processing operations easily.

In the summer of 1965 and 1966, teletypewriter terminals were installed at a local junior high school in Santa Monica, California. Students sitting at the teletype terminal and using a self-instructional TINT manual communicated on-line with the SDC computer several miles away. These children quickly acquired minimal programming skills and within a few weeks became rabid enthusiasts.

The Computer as an Instructional Tool

Computers are being used indirectly as a tool of instruction in that the problem-solving capabilities of the machine make it possible for students to handle problems that would otherwise be too difficult for them. For example, in an NSF-supported project, we have used the computer at SDC to provide students in statistics courses at local colleges with a matrix calculation capability that permits them to analyze experiments that would not otherwise have been possible due to the computational effort required.

Direct instructional applications of the computer have had mixed success. The
simple drill and practice applications for teaching arithmetic and spelling have
been very effective. Children rapidly increase their skill in such activities
under the pressure of computer-paced exercises. Other direct applications have
been less effective. For example, some efforts have used the computer simply
as a page-turning stimulus presentation device, merely putting programmed text-
books on the computer. Of the small number of courses that have been programmed
for the machine, many are restricted to very limited objectives and probably do
not require a computer to begin with.

Although computer-assisted instruction (CAI) has served well as a research and
demonstration tool, it is still in its infancy. It has not yet become a practical
instructional tool ready for widespread implementation in public schools; indeed
most of the problems that must be solved prior to its widescale application have
yet to be solved. However, the rate of development of on-line computer usage
for individualized instruction is very rapid and deserves serious attention by
school planners.

The research on CAI is moving away from the present emphasis on stimulus
presentation toward emphasis on response. There is a tendency for increasing
complexity in the methods of evaluating and processing student responses in
CAI systems. Programs have always evaluated student responses by comparing
them with prestored correct answers. That is, if a student made a spelling
or grammatical error his answer was incorrect. Special phonetic encoders and
keyword searching routines now allow CA^T programs to evaluate student answers
while ignoring spelling and grammatical errors. Thus, the student's answers
need not match perfectly the prestored correct answer in order to be considered
correct. Similar matching routines have been written for mathematical problems:
The student's answers need not be an exact duplicate of the solution used by the
author. The answer is correct if it is algebraically equivalent to the prestored
answer. Programs have also been written that complete the proof to a mathematical
theorem. If the student has supplied only one or two steps of the proof, the
program will verify whatever portion of the theorem was completed by the student
by finishing the proof.

Question-answering routines represent the next step on this continuum of response
analysis complexity. For example, at SDC a program called CONVERSE has been de-
signed to provide answers to questions posed in a limited subset of English. Using
an existing data management system, CONVERSE translates an English question into
one or more file-searching procedures. If complete translation is not possible,
the program provides a user with information that may help him in rephrasing his
question into acceptable English terms. CONVERSE accepts generic "browsing"
questions that ask for information about the data base as well as questions of
a more specific factual nature. As question-answering technology is perfected,
CAI will move much closer to a true Socratic dialogue and away from the programmed
textbook format.

Also at SDC, researchers have built a system that attempts to answer questions
from an encyclopedia. The first step in answering the question is to make a
search for the smallest unit of text in the data base, preferably a sentence
containing the intersection of the greatest number of content words contained
in the question. A simple information score (based on the inverse of the
frequency of the occurrence of the word in the large sample of text) is used
to weight some words more heavily than others in selecting potential answers.
The highest scoring answers are then retrieved from the tape on which the
original text was stored, for the student's answer. The approach is to
successively filter out more and more irrelevant information, leaving only
statements which have the highest probability of being answers to the question.

In addition, a study is currently under way at SDC to develop an improved
question-answering program for evaluating student performance by means of
syntactic and semantic analyses of the students' responses. A student's
question or answer will be analyzed for meaning and compared with prestored
information about the subject matter being taught. As a result of this
comparison, inferences will be made concerning gaps and irrelevancies in
the students' understanding. Appropriate questions and sentences will then
be generated by the program to assist the student in understanding the material.
Such an interactive CAI system will afford the student much more initiative in
guiding his own instruction. One objective of an interactive CAI system will
be to establish complex skills involving chains of verbal discourse leading
to the solution of a problem whose answer is not available from a simple
inspection of the textual material. Presumably, in the early stages, such
an interchange is overtly mediated by the natural language processing capability
of the computer. As this process of verbal discourse becomes internalized by
the student with extended use of such instruction, it is anticipated that his
generalized problem-solving skills will also be improved.

Undoubtedly there will be an age gradient in determining the extent to which
the student should control his own instruction. Younger children will require
more structure. Increasingly, the student's behavior will be relinquished to
his own control. Older students will benefit more from the unstructured question-
answering procedures and what might be called "library learning," which permits
them to search out their own information.

In addition to the structured-unstructured continuum, there is another dimension
along which computer applications to instruction can be described. Some CAI
systems are concerned primarily with verbal information presented in an abstract
academic context with minimal internal machine processing of student response
data. Other CAI systems simulate problem situations that are found in the lab-
oratory or in vocational settings with considerable internal processing of student
response data. The student is required to take decisive actions in response to
the simulated situations. The computer, in turn, uses these decisions in carrying
out the simulated process internally. The machine then presents to the student
the most likely "real life" consequences of his decisions. The object of such
instruction is not to teach the student to respond in certain ways but rather

to apprise him of the probabilities associated with various consequences that
are contingent on various alternative decisions. We have been experimenting
with the application of computer-assisted instruction in connection with our
simulation training program for the SAGE Air Defense System for over a decade.

One of the important by-products of this work is the discovery that such
training can markedly improve team performance. The computer is used to
mediate communication among various crew members. It maintains an accurate
record of all communications among staff members participating in the exercise.
Confrontation sessions following the training exercise typically lead to improved
interpersonal understanding and valuable suggestions for revising procedures
that were previously regarded as unchangeable. Thus CAI can make a very valuable
contribution in the domain of communication skills as well as in decision making.

The Computer as a Research and Development Tool

Most people are quite familiar with the use of library computer programs for
statistical analyses of research data. Such routines are particularly helpful
in analyzing data from field trials of new instructional materials. The results
of such analyses lead to revised sets of material which are tried again, evaluated
and revised over and over. Progressive improvement is expected from the use of
such evaluation-revision cycles in the development of instructional materials.
Evaluation-revision cycles could profitably replace the get-the-whole-job-done-at-
once-and-for-all-time method of developing instructional materials. The evaluation-
revision concept requires a commitment of school personnel or publishers to make
the product effective. The evaluation-revision cycle is essentially a built-in
self-corrective mechanism for quality control. It consists of defining a set of
objectives, evaluating discrepancies between the objectives and the performance
of the product, and continually changing the product to minimize the discrepancy.
The evaluation-revision concept is based on the assumption that no training program
will be completely effective in its first cycle of operation.

The evaluation-revision approach requires a substantial investment in time and
money to develop high-quality instructional materials that guarantee specified
behavior in the learner. Indeed, the cost of extensive evaluation-revision cycles
tends to be prohibitive. Consequently, researchers are presently exploring the
possible use of the computer to reduce the number of evaluation-revision cycles
required in the development of a set of instructional materials. Several ap-
roaches to achieving this objective are possible. One approach uses the
conventional CAI system to collect performance data from students on-line with
the computer. Data analysis routines summarize the performance data, and the
computer-editing capability allows quick changes to be made in the instructional
sequence. When the on-line evaluation-revision cycles have reached the point
of diminishing return, the instructional sequence can be published in conventional,
inexpensive media--books or films--and distributed widely.

A second approach, which is still in the research stage, is to use the natural language data-processing technology described above as a tool in screening first-draft instructional materials. A natural language data-processing program might accept as input first drafts of instructional material. Syntactic and semantic analyses of the instructional material would be conducted to detect gaps, irrelevancies, ambiguities, insufficient review, and inappropriate use of vocabulary prior to its definition. By using a computer to point out deficiencies in early drafts of instructional materials, a number of evaluation-revision cycles might be eliminated. Since the high cost of empirical testing of instructional materials represents a bottleneck to the construction of high-quality materials, this use of the computer represents an extremely important area of research.

A third significant use of the computer to develop instructional materials is in the generation of practice exercises. Once a well-defined format for frames or a defined mathematical form has been established, it is possible for the computer to generate thousands of examples in very short time. This area of research is still in its infancy but has considerable promise.

In addition to assisting in the design of frame content, the computer will probably play an increasingly important role in sequencing of instructional materials. Early studies have been conducted in search of an optimal strategy for the presentation of instructional items. While such research has not yet resulted in practical procedures for sequencing instructional material, the field is relatively young and should not be judged on its early return. The computer has been successfully used to sequence instructional materials by conducting frequency counts of various characteristics of running text. The instructional material can then be sorted along the various dimensions related to level of difficulty. For example, in reading materials, new words are introduced to maximize the number of new statements that can be generated with those words for beginning reading instruction.

The Computer as a Management Tool

Assuming that the persistent use of the evaluation-revision cycle leads to the development of extremely high-quality instructional material, it still isn't sufficient to merely send those materials to the teacher in the classroom. There are many management problems associated with the use of instructional materials. For example, which children should receive help? How much review should be provided? What materials should be changed? If these instructional decisions are to be based on sound data, an instructional management system is required to collect information, to analyze the information, and to display the information to the teacher in a form that is easy to interpret.

At SDC we are developing an instructional management system in cooperation with the Southwest Regional Laboratory which will function somewhat as follows: Student assignments will be completed on machine-readable forms. These forms will be read into a computer by an optical scanner. The data will then be

scored and analyzed by a program which will also record the student's
performance. The computer will generate printouts making it easier for
the teacher to monitor individual student performance. The printouts will
provide individual and group summaries of student progress. This information
will be summarized each day and will also be accumulated across time. In
addition, special diagnostic statements will be made concerning each student's
performance on specific instructional objectives. Furthermore, suggested
alternative activities and materials will be provided to the teacher on the
printout. Sample information to be displayed on a typical printout is shown
in Figure 1. If the teacher wants additional information about objectives,
students, or instructional materials, she has a teletype terminal in the
school on which to make queries.

The computer will also be used to assist the school administrator. For
example, we have developed a program called S-PLAN which assists the super-
intendent in the preparation of next year's budget. It allows him to make
provisional changes to salary schedules, inventories, staffing complement,
etc., and to assess the effect of such alternative courses of action on his
budget. The computer calculates the effect of his manipulation and gives
him immediate feedback about the consequences of such actions.

Computers have also been programmed to conduct counseling interviews. Infor-
mation retrieval programs have been built which help a student find what he
is looking for more rapidly in the library. Policy capturing programs using
linear regression techniques have been written making it possible to isolate
the factors that enter into an administrative decision. In addition, there
are many administrative data processing applications such as grade reporting,
classroom scheduling, attendance accounting, fiscal accounting, report gen-
eration, student data storage and retrieval, and reminder systems to allow
school personnel to request the machine to remember certain information and
to prompt them.

It is not unlikely that the application of the computer as a management tool
will receive widespread implementation in schools well before any of the other
three applications are realized.

II. COMPUTER OPERATING SYSTEMS FOR EDUCATION

A computer operating system consists of a set of programs that carry out
supervisory functions associated with the running of various object programs.
The executive program manages the allocation of storage space and serves as a
"traffic cop" for various object programs that are to be run. Object programs
are used to solve specific problems for different users.

An important type of executive system for educational applications is known as
time-sharing. Time-sharing systems allow many users to share direct on-line
simultaneous access to a single computer. Many of the applications I spoke of

BUILDING: CENTRAL
TEACHER: BEVERLY DOE   DATE: OCTOBER 19, 1967

B1 READING, GROUP 11
TEST 17, REDBOOK PP. 19-23

A. CHIPMUNK GROUP REPORT

OBJECTIVE	MARK THIS TEST	ACTIVITIES RECOMMENDED	CUMU- LATIVE MARK
VISUAL DISCRIMINATION	A		
WORD RECOGNITION			B
WORD PRONUNCIATION			B
ORAL READING			B
PHONIC ANALYSIS	D	001, 002, 003	C
STRUCTURAL ANALYSIS			C
WORD COMPREHENSION	C	116, 118	C
SENTENCE COMPREHENSION			C
PARAGRAPH COMPREHENSION			C
			C
GROUP AVERAGE	B		
			C

B. INDIVIDUAL REPORT

NAME	MARK THIS TEST	NUMBER OF TESTS TAKEN	CUMU- LATIVE MARK
LINDA WESTREM	A	15	
WILLIAM AKRON	A	17	A
JOHN FOSTER	B	14	B
PENNY WILLIAMS	C	16	C
ROBERT BERRAK	C	17	C
CHESTER SMITH	C	14	C
DIANNE LONGMAN	-	16	D
VIRGINIA CUNNINGHAM	-	15	A
GERALD SIMPSON	-	12	B
			D

Figure 1. A format for standard printouts of
student progress.

earlier in this paper depend on on-line interactive use, a technique made
economically feasible under time-sharing. Thus, 30 or 40 users at a time
may have direct, or on-line, access to a computer and may process their own
unique programs without the intermediary services of an operator or a programmer.
This mode of usage contrasts sharply with the familiar off-line or closed shop
procedures in which the user turns his program over to a specialist and par-
ticipates no further in its processing. Users of time-sharing systems, many
of whom have had little or no previous experience with computers, interact
closely and continuously with the computer.

Figure 2 shows diagrammatically the operation of a large-scale time-sharing
system. In such a system a central processor not only can handle time-shared
instruction of students, but could simultaneously perform batch processing
of such school administrative functions as record keeping and class scheduling.
A central computer facility may be tied to many schools within a large metropolitan
region. Each school would have terminals of various kinds of communicating with
the central computer. Some schools might even have small peripheral computers
to allow for a greater number and variety of terminals to be tied into the system.
Several school districts could share resources by tying into the same computer
facility on a regional basis. While one school may be running its payroll,
another school may be generating attendance reports, and a third may be conducting
automated counseling interviews. A fourth school may be allowing its mathematics
students to write and debug their own programs on-line with the central computer
for subsequent use.

A number of time-sharing systems now exist and have been operational for several
years. In most of these systems, direct access is permitted between the individual
user and the computer with a typewriter keyboard or display device. These computers
are typically processing more than one person's program at the same time. The
purpose of such systems is to allow a continuous dialogue between user and program.
These days it is popular to call any on-line system, a time-sharing system, but
it is worth noting that some of these so-called time-sharing systems limit the
communication of the user to certain operations; others give such slow response
time as to be virtually off-line. Still other systems, which are also called
time-sharing, do not provide on-line access to large files of data nor allow
separate programs to be run simultaneously; it is very difficult to use such
systems for many of the applications described above.

III. PROBLEMS IN USING COMPUTERS IN EDUCATION

There are three major problem areas related to the application of computers in
education: (1) the problem of facilitating man-machine communication; (2) the
problem of cost efficiency; and (3) the problem of user acceptance.
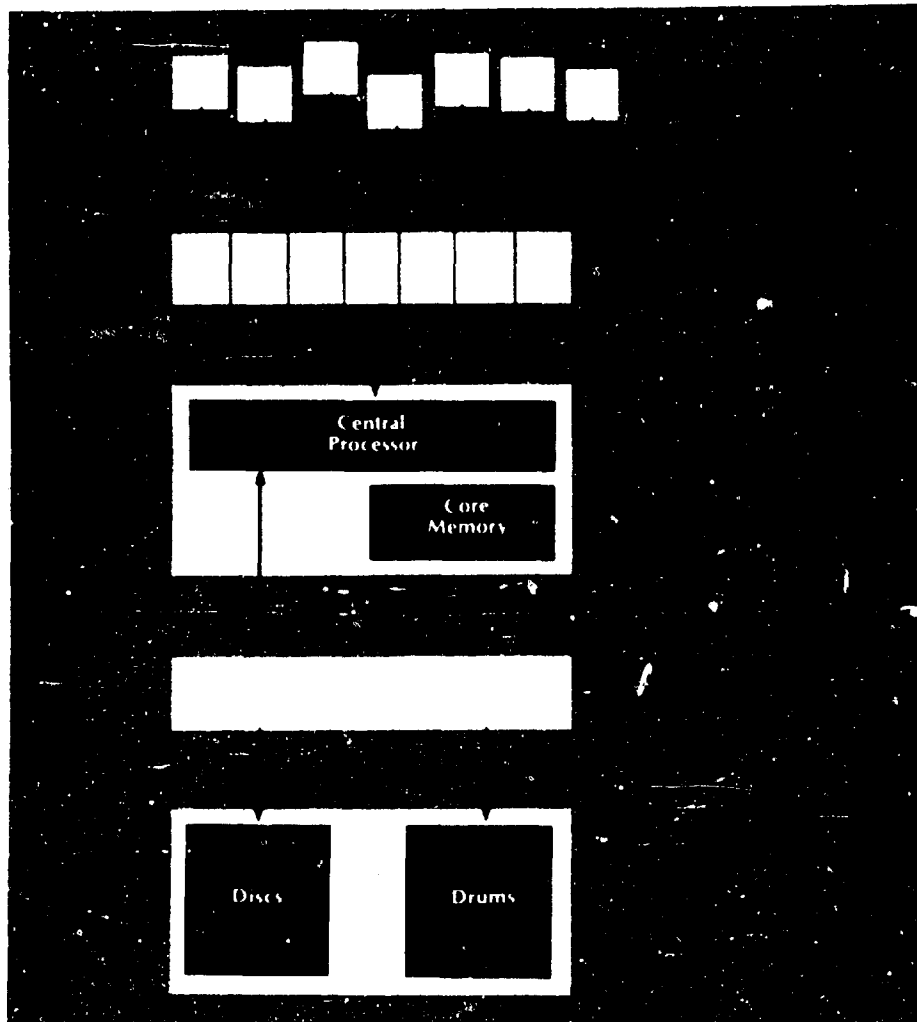
The typical large scale time-sharing system, such as SDC's TSS or its new system built around an IBM S/360 machine, will present an appearance similar to the above drawing. Central to the equipment configuration is the large, general purpose computer, around which are deployed input/output consoles, data channels and memory units.

Figure 2.   Schematic of time-sharing system.

Man-Machine Communication

Two factors make it difficult for people to communicate with machines. First, the terminals for inputting information into the machine and receiving information from it are not approproate for most educational applications. Secondly, the language that a computer understands isn't appropriate to the person who is attempting to communicate with the machine.

The most popular input/output device in use today seems to be the teletypewriter. Unfortunately, the teletypewriter is very noisy and very slow. The cathode-ray tube is an alternative to the teletype but it tends to have poor resolution and may be difficult for young children to read for extended time periods. Perhaps an alternative to either the teletype or the cathode-ray tube is the nonimpact printer which makes use of electrostatically charged ink sprayed on paper. This printer is fast, quiet, and easy to read, but it is still too expensive.

Very little in the way of new development for computer manipulation of sound seems to be in store for the near future. We must depend on computer addressing of tape recorders for audio. The picture is even more glum on the input of audio information into the computer, although Andromeda Incorporated, has developed a short vocabulary speech recognition machine, and Harlan Lane at Michigan is doing some research with recognition of prosodic features of language.

Bill Ramage at the University of Pittsburgh, Learning Research and Development Center, has been doing some interesting work on touch-sensitive and pressure-sensitive surfaces. Methods of inserting graphic information are developing very rapidly and it won't be long before we have practical methods of communicating with computers by graphical means.

The man-machine language problem is also receiving much attention today. Of course programmers have learned the artificial language of the machine and are quite at home in conversing with the computer. But it would be much more convenient for us if the machine would understand English, especially for educational applications. Some languages, called query languages, have been written to allow a human to obtain information from a machine in a compromise language representing a subset of English. But it still takes quite a bit of effort to learn a query language and the school user tends to be discouraged from bothering with the machine.

At SDC, we have developed an author language called PLANIT which allows a non-programmer to insert instructional materials into the machine for subsequent presentation to the student. This language is organized in multiple-choice form so the teacher merely responds to the machine's prompting concerning what is expected next. We have found PLANIT very easy to learn and at the same time extremely powerful and flexible.

Cost

Cost benefit analyses are becoming increasingly popular in our society as
a result of their successful application in the Department of Defense. The
purpose of such analyses is to select alternative systems that have the lowest
cost and the highest effectiveness. If benefits are much smaller than costs,
investment in the system is not considered feasible.

It is fairly easy to estimate the cost elements for computer applications to
education. One cost element for a computer system is the main frame. The trend
in miniaturization of circuitry promises to bring this cost element down very
rapidly in the near future. The production of such circuitry is being completely
automated and we can expect to see more small budget computers.

A second element is the cost of the terminals. Some new developments in
producing gas discharge "plasma" tubes promise to bring the cost of terminals
down somewhat. Perhaps we don't need such elaborate terminals for educational
applications. The increase in sales volume as computers come down in price
may also reduce cost of terminals.

Communications cost is a third cost element which doesn't appear likely to
go down very quickly, although work on communication satellites and laser
communications may someday alleviate the burden of this item. Hopefully,
such developments will produce a considerable improvement over the current
line cost. Perhaps eventual proliferation of low-cost computers may obviate
the need to solve this cost problem since each school unit may have its own
machine and can send tapes with data-base information to each other by mail.

Probably the most expensive cost element is the development, maintenance and
upkeep of high quality written materials and computer software necessary to
maintain the various applications we've discussed. For example, it has been
estimated that an average of 100 hours of author time is involved in the
development of one hour of student console time for instructional applications
of computers. There doesn't appear to be any easy solution to this problem.

Another problem related to cost is that computer programs written on one
machine facility will not necessarily run on any other machine facility.
Thus there is considerable duplication of effort. Until effective language
translation programs are written or until coding standards can be agreed upon,
the transferability problem will continue to make costs much higher than they
should be. The transferability problem interacts with the question of how
much money to spend on developing instructional material for computer systems.
If an extra 400 hours spent on a CAI program will only help a few students at
one particular school, the decision may be made not to go ahead. On the other
hand, if this material were usable or widely exportable throughout the country,
the cost would be considered negligible. Greater allocation of resources today
to developing metalanguages that are completely machine-independent may be a
more efficient way of spending educational development monies than to support
a large number of small scale CAI projects which are not transferable to other
systems.

Perhaps the most promising solution to the problem of making educational applications of computers feasible in cost lies with the large central procurement capability of the Federal Government, who could use this capability as an incentive to encourage manufacturers to design low-cost, special-purpose systems for the unique needs of schools and colleges.

It is much more difficult to calculate benefits than costs. One of the difficulties is that it is not possible to translate benefits to dollar values for comparison with costs. For instance, how does one translate a three-point improvement on the mean test score for beginning reading into percentage of reduction in school dropout at age 16, or into other items that are translatable into dollars?

Another problem on the benefit side is that careful experimental comparisons between conventional procedures and the various computer applications have not revealed uniformly practical differences in favor of the computer. It is interesting to speculate about the strong and persistent activity in CAI in the face of fairly limited evidence of learning benefits. Perhaps the reinforcer for the developer is the mastery of a new skill and the fun of making a novel application of the computer. It is sufficient for the developer that the instruction system works in a new fashion. Face validity may be the important factor in perpetuating many innovations that don't improve learning per unit cost over traditional methods.

Problems of Acceptance

One response to the question of acceptance is involvement of the user. Although school people will not be producers or manufacturers of computerized systems, it is important that they participate in designing the systems to be used in their schools. Marathon sessions between school personnel and system designers provide an opportunity for each group to confront one another, not only with their biases but also with their particular resources for the system design.

It is probably unwise for the manufacturer to start out by building a complete hands-off system that is supposed to anticipate everyone's needs. Rather a library of small modular program segments should first be constructed as needed. These procedures may be used as building blocks by different users. Teachers, administrators and other staff members may combine these segments in different ways to produce individual packages to meet their unique functional requirements. This is an evolutionary approach to system development. Instead of trying to sell a full-blown instructional system to a school, it is a better strategy to start with a single typewriter terminal that is tied into someone else's time-shared computer system. Then the only new item added to the school is a harmless looking typewriter. If staff members can have on-line access to the computer by merely sitting at the typewriter, and if there are available user-oriented languages to facilitate communication with the machine, then someone will soon be "hooked" on its potential.

Of course one of the prerequisites to acceptance of computers in education is
an effective staff training program. Simulation data can be used for providing
practice by potential users before the system is installed. The critical issue
in acceptance is to constantly remind the user of the human values to be served
by the system and the ways in which they are incorporated in one's design and
development work. Those values can all too easily be forgotten unless they
are kept constantly at the forefront of our attention.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author)	2a REPORT SECURITY CLASSIFICATION
System Development Corporation Santa Monica, California	Unclassified
	2b GROUP

3 REPORT TITLE

Applications of Computers in Education

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (Last name, first name, initial)

Silberman, Harry F.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
29 August 1967	15	

8a CONTRACT OR GRANT NO Independent Research	9a ORIGINATOR'S REPORT NUMBER(S)
b PROJECT NO	SP-2909/000/01
c	9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d	

10 AVAILABILITY/LIMITATION NOTICES

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY

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DD FORM 1 JAN 64 1473

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