TIME AND COST EFFECTIVE TECHNIQUES IN SUPPORTIVE COMPUTERIZED TRAINING SYSTEMS

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The computer that will respond to a raised eyebrow or a quizzical expression, carry on an interactive intelligent discussion with its human user, or recognize the difference between nervousness and lack of knowledge is yet to be invented. This is the stuff of which a teacher is made. These are the precious talents of the man or woman who stands in front of a class and nurtures the student's latent ability to reason. Such responsive activities still lie in the realm of human relationships and there they will remain for a long time to come.

Developmental efforts to find an appropriate place for the computer in the educational process have been gathering momentum for a number of years. Although no one has succeeded in endowing the computer with the facilities it needs to assume full tutorial stature, much progress has been made in utilizing it successfully in a supportive role. Even in such applications, however, it has not received the acceptance it merits. Aside from the resistance of the teaching fraternity to the introduction of impersonal educative devices and the unavailability of good course material in many disciplines, high costs account for the relatively sparse usage of computer assisted instruction (CAI) throughout the nation.

In order to evaluate the techniques and procedures we have developed at the New York Institute of Technology for improving cost effectiveness, let us look briefly at the principal factors which have thus far made computerized instruction prohibitively expensive for most school systems and training centers.

The first item is, of course, the high cost of the computer system which includes the central processing unit and all the required peripheral equipment. Outright purchase of even a comparatively small system is outside the limits of most school budgets; for example, a recent quotation for a popular minicomputer configuration suitable for CAI ran upwards of $60,000.

Secondly, for interactive on-line operation, the student must work at a computer terminal. The least expensive teletype terminals sell for about $400 apiece while the quieter, much-to-be-preferred video terminals cannot be purchased for much under $1,200 each.

A number of schools in the Long Island area have elected to rent time in an existing computer at another nearby institution. This practice solves one problem but introduces another: the need for a telephone line and a telephone coupler. Normally, a coupler and line are obtained from the 'phone company on a lease basis at about $80 per month, one set for each terminal. With heavy use, the telephone charges added to the rental fees may mount to figures that make this scheme economically unsound.

Educators who once considered a movie film or an audio tape the epitome of useful educational technology have just begun to display a real, active interest in CAI largely because of the convincing innovative developments taking place in this field. It seems a pity to allow the cost barrier to bring this growing enthusiasm to a grinding halt. And it is not particularly helpful to point out that computer and terminal prices have been steadily dropping so that in a few years--maybe--everyone will be able to afford CAI. We want CAI programs designed, written, and implemented now, not next year or the year after that!

What can we do about it?

There are several avenues that may be followed to reduced costs, each one contributing a small bite in the budget superstructure, but adding up to a significant improvement in the picture. Most of the techniques to be described have already been implemented at the New York Institute of Technology; others are in the process of being tested with small groups of students. At the time of writing, our programs are running on a XEROX SIGMA 6 computer configuration under UTS (Universal Time Sharing operating system). Only a very small portion of the computer's total time is dedicated to CAI, the rest being consigned to the college's administrative and supervisory tasks. Despite the ready availability of this machine, however, we have written our programs and designed our file systems with a minicomputer in mind so that, when the time comes, our work will be handled by a small machine completely dedicated to education.

Suppose we consider basing our designs on a $60,000 minicomputer which we shall rent rather than buy outright. (This has the additional advantage that adjustment and repair service goes along with the rental fee.) Rental figures are normally based on one-sixtieth of the purchase price per month, hence this configuration would go for about $1,000 per month. This particular system is designed to handle up to 16 terminals simultaneously and, to make full use of its capabilities, we would want to rent this number of terminals at approximately $50 per month each for a total of $800 per month. The 16-terminal cluster would then be set up sufficiently close to the minicomputer assembly to permit direct wiring, thus avoiding the use of costly telephone lines and couplers.

Next, let's set the operating hours for the interval from 8:00 a.m. to 10:00 p.m. to service both day and evening classes, daily for 20 days per month. For 16 terminals, this provides a total of 4,480 terminal hours per month. Thus, assuming a full load at all times, the final cost figure turns out to be a little over 40¢ per terminal hour. Realistically, however, scheduling difficulties and turn over times from student to student tend to reduce the connect time to perhaps 60% of full load, so that it would probably be closer to the truth to estimate the cost at roughly 60¢ per terminal hour. *Whether or not this is a cost effective figure for one hour of individualized instruction depends entirely on the quantity and quality of the education passed on to the student during the session.* This consideration will be held in abeyance for the moment.

There is another question that needs to be answered: what is the maximum number of students that can be adequately serviced by the system under discussion? It is not uncommon to find in well-equipped military installations a terminal schedule that calls for upwards of 30 connect hours per week for each student. At this rate, the system will handle only 35 students without the incidence of scheduling conflicts, assuming in the first place that the schedules were generated without error. Clearly, costs can be reduced by limiting student terminal time to as small a figure as possible without a serious loss of the effectiveness of instruction. For example, the system will service 350 students if each individual's connect time is limited to 3 hours per week. The one salient remaining question is: can CAI be effectively presented and monitored with individual student terminal time limited to this extent? This question is closely linked to the italicized statement above. The key to the entire problem of cost effectiveness lies in the nature, design, and quality of the course software--in the strategies employed to present the CAI to the student and the methods used to elicit the desired interactions. To this end, we might begin by agreeing on a very simple guiding principle:

> *The computer is to be used only for those activities in which it clearly surpasses all other media.*

The application of this principle to actual CAI courseware is illustrated by examples taken from the New York Institute of Technology inventory.

<u>TEXT STORAGE</u> - Voluminous text material belongs on a printed page, not in a computer printout. The textbook or worksheet is still the best place to store information for student readings. The work of the computer may be related to the printed page in a variety of ways; it can ask questions about the reading material, supply words or numbers that have been intentionally omitted, select routes for the student to follow through the text based upon his responses to questions, and monitor the student's progress through the lesson.

The Educational Management Information System (EMIS) now in use at NYIT consists of a series of sophisticated programs and files which can administer, monitor, and record individual student work in subject matter review-drills and tests. The intent underlying its design is that of making available a large number of objective questions of all types to serve as criterion checks and achievement indicators without the logistical absurdities that normally accompany such an endeavor. All of the questions are written in five different versions and appear in question books used by the student at the terminal. The question versions are thoroughly scrambled in the book, each one identified by an item number and each one missing a key word, number, or phrase. The computer supplies information relative to the item number of the version that the student is to answer and the missing key word. Thus, the bulk of the text material is stored in the question book; all that need be stored in the computer are the item number and the key word. A substantial economy of disk storage space is thus effected, making the system available for a large number of different courses without the need for expanding the computer's storage capabilities.

The "printed-sheet" tactic is also used in presenting enrichment problems, diagnostic problems, and simulated laboratory exercises in the sciences. Before the student is scheduled for terminal time, he is given a worksheet which contains all of the information he needs to start planning his attack on the problem or laboratory exercise. When he reports to the terminal room, he has already completed from 70% to 90% of the job in each case. The computer's function here is one of supplying specific data for use in solving a problem that the student has set up in general terms, checking the student's reasoning and numerical manipulations, and recording the effectiveness and accuracy of his thinking. This approach permits significantly large reductions in connect time.

<u>GRAPHICS</u> - Computer terminals capable of generating graphics of many types are now available but are very expensive. Here again, to realize reductions in costs, we store our stock diagrams and graphs on the printed page except in rare cases where an ordinary inexpensive terminal can quickly generate them. Admittedly, it is "nice" to have the computer draw a diagram while the student watches, but in most cases the process is one of gilding the lily. The educational advantages of such procedures is highly questionable, particularly in view of the phenomenal increase in costs they entail.

<u>SOCRATIC METHOD OF LESSON DEVELOPMENT</u> - Supportive CAI, by definition, avoids those procedures which are best left to the human teacher. It does not pretend to develop and teach the course. It functions to enrich, drill, test, monitor, and remediate. Its usefulness rests upon the presupposition that the basic teaching is being handled by conventional classroom methods or by a self-paced, individualized program under the constant supervision of a live teacher. Aside from these rationales, prime instruction by computer violates our guiding principle and results in enormous increases in student terminal time.

<u>RANDOMIZATION</u> - The ability to randomize data supplied to the individual student for use in both enrichment and remedial problems is one of the fortes of the computer approach. A number of students sitting side-by-side at their terminals will be provided with different data for solving the same problem, the data having been selected at random between

reasonable limits preselected by the programmer. The random number function of the computer is also used to choose one version of each question in the EMIS so that drills and tests vary in question statement and numerical content from student to student. In our simulations of laboratory experiments, we use the random number function in still another way: to serve as a reader of imaginary instruments and scales, providing data with built-in errors (between desired limits, of course) in order to simulate the natural variations which occur from one run to the next. For example, a kinematics experiment in physics based upon a large air track involves the acquisition of data for successive trips of a glider, given a specific inclination angle for the track and a specific path-length. For each run, the student chooses the path-length he wants but the computer randomly selects the angle of inclination and then provides time data for five successive runs of the glider. The range of variation built into the time data randomization to simulate real-world results is set in advance by the programmer; in most of our lab simulations, we use a variation of ±2%.

MANAGEMENT - Computer Managed Instruction (CMI) is often discussed as an entity in itself so that one might easily get the impression that it is unrelated to CAI. Although CAI may be implemented without CMI, and vice versa, to do so would be to ignore a valuable and unique computer capability. The management function may include some or all of the following activities: automatic grading of tests and drills, maintenance of data on student performance and course item validity for projected statistical analysis, interactive route guidance in individualized study (i.e. computer selection of branching paths based upon the student's responses), calculation of desired statistical information, and printing out of lists and reports for the instructor's use.

In particular, the EMIS combines CAI and CMI in what we consider to be an effective form. Tests and drills are taken on-line. Grading and recording of data is then automatic. The data thus entered may be retrieved in the form of one or more reports accessible upon request by the course author or the instructor. Instructors may move students from one class to another, insert or remove flags of various types, change previously established passing grades, and so forth. A grand total of over 17 different reports and lists may be readily obtained on demand.

Management of a somewhat different type is embedded in the programs used for diagnostic problems. In the physics course, for example, a record is kept of the number of "tries" that a student makes in determining the names of the variables described in the problem, their symbols, and the correct equation(s) required for the solution. At the end of the day, the instructor retrieves this information about each student and is thereby aided in determining the source of a "hang up" if one exists.

CALCULATIONS - Referring to our "guiding principle", it is in the domain of calculations that the computer quite naturally excels and can slice student connect time to the absolute minimum. Much of the CAI at the New York Institute of Technology deals with physics and mathematics where calculations, often involving intricate equations, are common. To see how this time-economy is realized, consider the following example:

A student has been assigned an enrichment problem in physics in which he is to locate the gravity-null position between two celestial bodies. He has been issued the worksheet for this problem and is asked to derive a general equation for its solution before reporting to the terminal. The worksheet tells the problem "story" and makes it clear that a final numerical solution is unacceptable in fewer than six significant digits, therefore making it impossible to use an ordinary slide rule.

When the student begins the program at the terminal, assuming that he has derived the required equation, he is taken through a series of interactions in which he finally acquires randomized values for the mass of each of the bodies and the distance between their centers of mass. At this point, he is asked to calculate the position of the gravity-null point along the line joining their centers and then input the final answer. The complexity of the equation and the significant-digit requirement of the problem are such that the student would need a half hour or more to obtain the answer by the paper-and-pencil method, even if he were a fast mathematician. Throughout this time, the computer would wait patiently for the answer, extending the connect time intolerably. Obviously, we don't do it this way! When the computer requests the answer, it immediately goes into the keyboard mode which gives the student the privilege of using it as a calculating machine. He simply inputs his equation, the mass values, and the distance value and then calls for a printout of the answer. Even for a novice, this requires but a few minutes. Finally, he enters the command to resume the program so that he may type his answer. His work is then automatically checked for accuracy; if it is correct, he is congratulated and sent on to other related materials in the worksheet; if his solution is wrong, he is asked to repeat the calculations using the same data. Should he fail to obtain the right answer after three tries, he is logged off and sent on to his instructor for help.

The simulated laboratory exercises offer the same option for performing keyboard-mode calculations should the student prefer this to his slide rule--and most of them do.

Another aspect of laboratory simulations must be mentioned here. The first reaction of a teacher of hard science to this concept is usually one of unmitigated horror! And quite justly so. He is quickly mollified, however, when he learns that we do not delete or replace any of the existing hands-on exercises by simulations but rather make it possible for the student to "perform" an experiment that he could not otherwise do under normal circumstances. Our exercises are structured around equipment which is too costly or too bulky for the school to stock in sufficient quantity for individual laboratory work. For example, it is not always possible for a school to set up more than one three-meter air track, or particle accelerator, or bubble chamber. In these instances, a teacher might demonstrate the action of the device to give his students the "feel" of the equipment and then let each one run through a simulation in which he does everything except take readings on real instruments. We have found that the degree of enthusiasm displayed by students for this kind of work depends to an enormous extent upon the motivation provided by the worksheet and the care taken in writing the computer program. At the moment, we are starting to produce a series of brief movie films to serve as preludes to the execution of the simulations; we feel that they will be of substantial help in establishing the sought-for atmosphere as well as in providing firmer motivation.

This discussion has been based upon a minicomputer configuration because this is the way most training institutions will go, especially if their CAI and CMI efforts are still in the preliminary planning stages. For schools that are fortunate enough to have access to a large machine already on the premises or near by, there are a number of economy measures which deserve careful consideration in connection with general system design. Some of these have already been mentioned in the foregoing discussion but may well bear repeating...

In considering the programming languages available for use with the XEROX SIGMA 6 at the New York Institute of Technology, we settled on extended BASIC for reasons of compatibility and ease of use. Programs written in this language can, with trivial changes at most, be transferred to almost any minicomputer now on the market. Possibly more important than this, interested members of school departments can be trained to write programs in BASIC with a minimum of instruction. Most of the ideas for new and viable supportive CAI approaches emanate from the faculty; if the teachers have even a modicum of experience in actual programming, they tend to develop a healthy independence of professional programmers at least for trial runs of their ideas, and often for complete program structures.

In most cases, existing large machines are heavily committed to operations other than CAI and CMI, and so every effort must be made to conceptualize and implement these strictly educational efforts in the most efficient manner. By storing text on the printed page, a substantial saving of disc space is effected; by using modular programs, a similar saving of core space is realized.

Additionally, the EMIS design incorporates cost-effective measures such as direct access disc techniques to save machine time, hash-coding to store course material so that minimum seek time is achieved, limited dialogue to minimize overload by a large number of terminals, and a relatively large amount of off-line work by the student to keep the connect time as low as possible.

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