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ABSTRACT

This paper focuses on Computer Managed Instruction (CMI), the use of computers in managing the instructional environment. Discussed topics include: the uses, levels, and need for CMI; the relationship between CMI and technology; CMI and adaptive or individualized instruction; and operational aspects of CMI. Science and nonscience uses of CMI systems are documented, and some projections for developing CMI in an academic environment are discussed. (MH)

SCIENCE EDUCATION AND COMPUTER MANAGED INSTRUCTION: THE STATE OF THE ART*

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Overview

In this paper the growth of the use of computers in education (Computer Based Education) will be summarized. The focus will turn to the use of computers in managing the instructional environment (Computer Managed Instruction). This includes definitions, uses, levels, the need for CMI, the relationship between CMI and technology, CMI and adaptive or individualized instruction, and operational aspects of computer managed instruction.

The next section will document some exemplary science and non-science examples of computer managed instructional systems operating in this country at the present. Under the topic of science application we will examine application with traditionally-organized instructional and non-traditionally organized instructional programs. Under the non-science areas, we will examine military and university applications with high potential for usability. We will also examine briefly a projected model called GLS, or Guided Learning Systems, which is at present being reviewed by the National Science Foundation. Next we will turn to some projections for developing and applying CMI in an academic environment. Finally, a list with some conclusions which seem to be derivable based upon the current level of activity and projected levels of activity of CMI will be discussed.

Growth of Computers in Education (CBE)

Much can be said about the use of computers in the educational or instructional process. A basis for the instructional approach used in CBE ventures can be found in "A Review of Developments in Computer Assisted Instruction" (Feldhusen and Szabo, 1969). In this article, the authors trace highlights from the foundational roots of CBE from the educational technology field of programmed instruction. Sidney Pressey was one of the early pioneers in developing the teaching ma-

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chine. Later B. F. Skinner attempted to automate instruction and became quite famous throughout the world for his research and views. Skinner's work is sometimes associated with a negative reaction to the automation of instruction in that it opened the way for the criticism that automating instruction was depersonalizing and dehumanizing.

Researchers at the International Business Machine Corporation in 1959 developed a course to teach stenographic skills. One of the persistent problems that plagued the CBE movement in these early years was that most computers used for educational purposes were originally designed for business applications. Their operating systems were not uniquely designed for the specific requirements of educational or instructional applications. The considerable modifications required have never proven wholly satisfactory.

Although the adoption of computers in instructional uses has been gratifying, it has not lived up to the many expectations for computers generated during the middle 1960's. Mitzel (1974) has discussed the delay in the application of computer technology to education as related to the following five points:

1. A major amount of capital investment is required for equipment acquisition.

2. A lack of adaptability of business oriented hardware to the computer based educational movement.

3. A highly decentralized educational market.

4. A lack of resources for developing even the minimal amounts of computer based course material.

5. A prevailing skeptical anti-technology attitude among teachers and other educators.

Another problem related to slow development has parallels in instructional television and programmed instruction. Proponents of both instructional television (ITV) and programmed instruction (PI) were quick to promote their product with great enthusiasm. In hindsight, they were probably guilty of having their statements misread by innovation-sensitive persons as indicating that their products would provide a panacea for all educational problems. When this did not materialize, both PI and ITV suffered severe setbacks. In fact, outside of military applications and a few minor operations in this country, PI is maintaining a very low profile. Interestingly enough, however, in some foreign countries such as Great Britain, a great deal of PI is being utilized. ITV is making somewhat of a comeback now in part because some ITV producers and educational programmers have realized that there are many uses of ITV which are quite inappropriate for specific objectives. Similarly, there are some objectives for which the use of computers may be inappropriate (e.g., electronic page turning) and other objectives congruent with computer applications. The intensive management problems in education and the usefulness of the computer in management in industry seem to be designed for a perfect match. Although the growth of CMI seems to have a promising future, one must be cautious about such predictions in the light of recent events in instructional television and computer assisted instruction.

Scanlon (1974) listed factors which would either support a dramatic increase in the use of computers in schools or would negate the increased role of computers. Under the former category are the decreasing costs of computing, the increasing availability of software, the emphasis on accountability, the movement toward individualization of instruction, and the need for more productivity. The arguments supporting a limited role include the potential for depersonalization, the limited financial resources for technology, resistance from traditional teachers in unions and lack of data on the cost/effectiveness in instruction.

Definitions

One of the basic dilemmas generally encountered in a discussion of technology in instruction arises over the meaning of the term "technology." It becomes a useful reference to point to the report of the Commission on Instructional Technology (Tickton, 1970) and the way in which they dealt with the issue.

> Instructional technology can be offered in two ways. In its more familiar sense, it means the media born of the communications revolution which can be used for instructional purposes alongside the teacher, textbook and blackboard. In general, the Commission's report follows this usage. In order to reflect present-day reality, the Commission has had to look at the pieces that make up instructional technology: television, films, overhead projectors, computers, and the other items of "hardware" and "software" (to use the convenient jargon that distinguishes machines from programs). In nearly every case, these media have entered education independently, and still operate more in isolation than in combination.

> The second and less familiar definition of instructional technology goes beyond any particular medium or device. In this sense, instructional technology is more than the sum of its parts. It is a systematic way of designing, carrying out, and evaluating the total process of learning and teaching in terms of specific objectives, based on research in human learning and communication, and employing a combination of human and nonhuman resources to bring about more effective instruction. The widespread acceptance and application of this broad definition belongs to the future. Though only a limited number of institutions have attempted to design instruction using such a systematic comprehensive approach, there is reason to believe that this approach holds the key to the contribution technology can make to the advancement of education. It became clear, in fact, as we pursue our study that a major obstacle to instructional technology's fulfillment has been its application by bits and pieces (pp. 21, 22)

It will be useful for the reader to address the subject of CMI keeping in mind the distinction between these two uses of technology.

Let's turn to some definitions or terminology relative to the use of computers in education. The term that generally encompasses the total area of the use of computers in education is "Computer Based Education" (CBE). CBE includes the use of computers to support or implement interactive information processing associated with human learning. The term "interactive" eliminates from my definition of CBE the notion of batch processing, although there are numerous applications of computers in education which do rely wholly or exclusively upon batch processing.

The computer based education movement can be broken down into three subcomponents. These are called Computer Assisted Instruction (CAI), Computer Managed Instruction (CMI), and Computer Simulated Instruction (CSI). A related area is the use of computers to study artificial intelligence (AI). In an artificial intelligence framework, the objective is to teach the computer itself to (think) like and therefore emulate the mental operations of a human being. Numerous AI applications exist; two of the more prominent ones are based here in Boston. Professor Seymour Papert at MIT and John Seeley Brown at Bolt, Beranack & Newman are both conducting interesting AI studies. Although the focus my talk is on computer managed instruction, it is useful to discuss CAI and CSI in order to sharpen the distinction between CMI and the latter.

Computer Assisted Instruction

CAI generally refers to the use of the computer in a direct instructional application; that is, information transmission and processing in which the chief concern is to provide instruction to a student. One example of CAI is complete self-contained courses which are in operation at various college and university centers.

CAI has taken advantage of three chief features of the computer which are quite useful in instructional applications (Hall, 1971). First, a computer has the ability to store data and algorithms and use these stored data or algorithms to evaluate responses of students. Second, computers are able to interact in a real time with students' responses. In a good high-speed CAI environment the time lag between the entering of student response and the forthcoming response by the computer is negligible. The third characteristic is the computer's ability, through careful curriculum and instructional design, to individualize various parameters of the instructional situation. For example, the computer can tailor the rate of presentation and thus adapt it to an individual learner needs. In addition, the computer can operate at the appropriate level of achievement for each individual student and carefully govern the sequence, feedback, and remedial loops. In a CAI format, the computer can deliver direct instruction, provide remedial help to a learner, make branching decisions based upon the on-line performance of the student in the particular subject matter, guide the learner through a problem-solving situation, or provide numerous other instructional activities.

Computer Simulated Instruction

CSI refers to the use of simulations in an instructional setting. A simulation, of course, is a representation of some aspect of reality with factors and variables that may change during the course of operation. A computer simulation of a complex ecosystem or the Lorenz transformation in physics is quite easily presented to an individual student on an interactive basis.

Perhaps some of you are familiar with the chemistry lab simulations produced by Professor Smith of the University of Illinois or the fruit fly simulation on the University of Illinois PLATO System. Another simulation was developed at the University of Illinois at Chicago Medical School computer program. In this series of simulations, a doctor is provided with patient information and is requested to query the computer using natural language to identify needed information about the condition of the patient so that he can make a diagnosis. The doctor prescribes his treatment for patient management;

the computer immediately carries out his instruction and provides immediate feedback as to the change of the patient. The University of Illinois Medical School simulations are now being modified to fit into the Ohio State University medical program under the direction of Dr. Pengov.

A major factor in the application of simulations is the psychological excitement generated by participating in a simulation. Nothing causes a physician to turn white faster than realizing he has just "killed" his simulated patient. And the work of Boocock and Schild (1968) at Johns Hopkins University has shown that games and simulations can be extremely powerful learning experiences.

Two types of simulation are in operation today. The static simulation operates with a set of prestored data and information in its memory bank and uses some keyword search routine to match requests for information from the student with the prestored data. Generally the data base does not change as the simulation proceeds in a static simulation. In a generic simulation, however, the data base is alive and interactive. It may change from moment to moment during the simulation in accordance with decisions made by the student or decision logic.

One of the more potent applications of a generic simulation is represented by the work of John Seeley Brown of Bolt, Beranak and Newman. John has programmed a computer to simulate a DC power generation circuit. The number of components in the circuit is quite large and the number of hypotheses about malfunction is staggering. This computer simulation (SOPHIE) does not prestore possible malfunction conditions; rather it is capable of generating all possible malfunctions based upon complex circuit equations. For each malfunction it generates a natural language hypotheses to compare with the hypotheses that the trouble-shooting electronics student puts into the system. The student may request the state (e.g. voltage, current) of any component at any time and can replace any component at will. Each replacement action is related to a specific malfunction hypothesis. The simulation can check any incoming hypothesis against internally generated hypotheses and even inform the student of the number of hypotheses he hasn't considered.

These and other simulations are modeled in a large sense after industrial simulations (e.g., the simulated landings on the moon and simulation training of 747 pilots).

Computer Managed Instruction

CMI represents a relatively new mode of computer involvement in the instructional process and derives from the concept of management by objectives from the world of business. Relative to CAI, CMI represents a less intensive use of computers which has been, up until recent years, passed over by educators.

Hansen (1974) has identified a list of applications or uses of computer managed instruction in educational settings.

1. Diagnostic and microscopic evaluation with feedback and prescription of student learning.

2. Student counselling.

3. A scheduling function to optimally match students, resources, and time.

4. The development of appropriate records keeping capabilities.

5. The printout of student performance records for students, instructors, and administrators.

6. The expansion to manage the resources of CAI.

7. Test item selection based upon item statistics.

8. Individualization of instruction.

CMI stops one step short of providing information to the learner although, depending upon the type of feedback given for an examination situation, computer managed instructional environment can provide a good bit of direct instruction. In most applications of CMI and associated instruction, it is desirable to clearly separate the functions of the computer and the rest of the learning system in such a fashion that a computer managed portion manages assessment and other resources in the learning environment while the rest of the environment provides the instruction. For example, a course might be set up in such a fashion that students meet with an instructor during regularly scheduled times. Reading assignments, lecture notes, and laboratory assignments are all handled on a regular basis. When the time comes for students to demonstrate what they have learned from the course, either in a diagnostic-prescriptive or evaluative situation, the student presents himself at a computer terminal and takes a searching examination of specific subject matter of concepts.

Mitzel (1974) has identified three levels of application of CMI. By our previous definition of computer based education which dictates an interactive use of computers, the very first level does not fit. Nevertheless, Level I, which utilizes batch processing for test scoring and item analysis procedures will be mentioned. Almost all Universities have established an exam analysis service. With this service a faculty member can use a special mark sense format answer sheet and correlated tests. The answer sheets are then sent to an exam service which reads the scores and provides a computerized score printout and item analysis. This is usually done in a batch process mode; consequently there is a great deal of time between test administration and scoring. This time is usually of such a magnitude that the effectiveness of the feedback to the students is lost. In addition, the exam scoring services of universities on a batch process mode are more often than not utilized in an end of course examination mode; this precludes the results being used to impact the student's learning program and dictates a purely evaluative function. The conscientious instructor can utilize the item analysis information to improve his test for future generations of students but for those students who have just completed the course, their chance is past.

The second mode of CMI identified by Mitzel includes on-line interactive testing at a computer terminal with the data collected and batch processed for item analysis and summary reports. Although the disadvantage of this system is that the student must wait for some period of time for the actual summative results, he can obtain immediate feedback on an item-by-item or objective-by-objective basis at the conclusion of the examination. In addition, the results can be fed back to the student on a regular (weekly) basis allowing the instructor and student to determine and implement corrective measures. Level II represents a step up from Level I in that it does provide immediate feedback to the learner and enhances the probability of his acquiring knowledge from that particular educational experience.

The third level is represented by on-line testing, feedback, diagnosis, prescriptions, and scheduling options. It would be useful to briefly describe each of these five areas and to expand upon them.

Testing, of course is the administering of examination items to individual students for specific purposes. A distinct advantage of a CMI system, however, is that a student, depending upon availability of terminal time, can schedule a test whenever he feels he has appropriately learned the subject matter. Under conventional situations, this action is not possible for numerous reasons such as instructor time and availability and maintaining security of the items.

Feedback or knowledge or results of performance is the provision of test performance results to the student. The computer can provide an individual item-by-item feedback or a summary feedback at the end of the examination session. This is highly unrealistic for an instructor to accomplish when the number of students in the class exceeds thirty.

Diagnosis has its analogy with the medical profession. An examination can be used to diagnose specific learning problems, particularly when the items are grouped together to measure specific objectives of an instructional program. It is easy for the computer to be programmed to identify which specific objectives a given student has and has not mastered. Prescription is an analogy drawn from the medical profession. Once a person's difficulties are diagnosed a prescription is made. A physician does not take his prescriptions lightly, nor should the instructor. These prescriptions should be keyed very specifically to the diagnosed learning difficulty. In the eventuality that the problem still persists even after the first prescription, the instructor should be prepared with an alternative prescription which has been tested and shown to be effective in numerous situations.

The final point is scheduling. If a course is managed by computer, there are certain activities and resources such as laboratory exercises which require group participation, laboratory space, and equipment, chemicals, facilities, and time which need to be brought together for effective learning. It is possible to manage all of these factors with students and with the use of a sophisticated CMI system. In summary, CMI started as a management and recordkeeping system but evolved to provide the teacher with the tools of management via computers.

CMI and Adaptive Education

Individualization of instruction seems to be a theme which constantly recurs in educational literature but thus far has not made a great deal of curriculum headway into instructional programs. One reason for this lack of headway of individualization of instruction is the lack of a management strategy to actually handle individualization. A typical classroom instructor has all he or she can do to keep track of a class of thirty students who are engaged in similar instruction simultaneously. Imagine the confusion that results when the curriculum is individualized in which thirty students may be progressing in thirty different directions at different rates and all needing to be checked out on the different competencies at different points of time.

What is meant by individualization of instruction? The goals of individualization might be listed as the mastery of subject matter, the development of self-directed and self-initiated learners, self-evaluation, or indepth learning of instructional materials. Ralph Tyler, the father of behavioral objectives, has identified five different interpretations of the term individualized instruction. It can mean that the student:

1. is allowed to proceed through content materials at a self-determined pace;

2. should be able to work at convenient times;

3. should begin instruction at a point appropriate to past achievement, interest, or learner characteristics;

4. is inhibited by a small number of easily identified skills or knowledges; or

5. is furnished with a wealth of instructional materials from which to choose (the multi-media approach).

One enticing but pervasive area of individualizing instruction is individual learner differences. Bolvin (1974) has identified six areas of individual differences that now seem to be of concern to educators. These are:

1. Differences in entering level of achievement among students in a given class.

2. Differences in rate of learning toward certain fixed goals for a course.

3. Differences in gross learning styles by having available a limited variety of resources and materials.

4. Those individual differences among students that relate to student teacher interaction needs.

5. Certain select subject goals for some students and not for all.

6. A limited degree of attention to individual differences relating to differences in attitude and motivation of the learner toward learning in instructional tasks.

One of the potential applications of CMI is to more nearly individualize or adapt instruction to individual learner needs and individual differences of students.

Examples of Operational CMI Systems

It is not known at the present time how many CMI systems are in operation around the country. Twenty-nine systems were described at the 1974 Conference entitled "An Examination of the Short-Range Potential of Computer Managed Instruction" sponsored by the National Institutes of

Education and Penn State University (Mitzel, 1974). The examples presented at this conference ranged from high school to college and university to military and to industrial training applications. It is likely that there are another thirty systems by now operational around the nation and abroad. For example, the new University of Ulster in Ireland is conducting a CMI project named Project CAMIL.

Science - EMIS. Two examples have been selected from the area of science instruction. In the first example, a CMI system has been mated with what I will call a more traditionally-organized type of course structure. It is named "The Educational Management Information System" or EMIS for short. EMIS is used at New York Institute of Technology, at a nearby public school, and was developed by B. Ward Deutschman and Harvey Pollack. The following excerpt from the Conference Proceedings by Deutschman (1974) gives an overview of EMIS.

> "The Educational Management Information System (EMIS) 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 study and test material may be presented to the student either on-line or as computer-printed hard copy prepared in advance. The intention of EMIS is to provide a large number of objective questions of all types to serve as criterion checks and achievement indicators. EMIS, designed by Dr. Harvey Pollack, is a combination of CAI and CMI. The EMIS presentations are supportive and supplementary to classroom instruction, self-paced individualized study, laboratory experiences, and auxiliary audio-visual aids. In the on-line mode, every student's response is evaluated and recorded for future statistical analysis and the student receives his score immediately after completing the bank of questions for that topic. EMIS is a chained assembly of a number of computer programs and files. All of these have been written in extended BASIC so that they may be loaded into any large computer or mini-computer with minor modifications. Currently, the EMIS programs are running on a Xerox Sigma 6 computer, operating under universal time-sharing operating system.
>
> EMIS produces reports for the student, instructor, and curriculum designer. Each user has access to specific course information predetermined by the EMIS developers to secure materials security and test integrity. The reports offer: records of individual

student progress, analysis of individual performance for remediation, records of cumulative class progress, analyses of strengths and weaknesses in question categories, cumulative item analyses, and indications of the existence of trouble flags" (page 35.)

The following senario provides a description of the operational features of EMIS. At the start of the semester, each student is issued a topical catalog of the banks of questions available to him listed in syllabus sequence. There are 47 banks in the Physics A student catalog with sample topic titles such as: Significant Figures, Scientific Notation, Linear Motion, Force and Motion, Momentum, Gravitation, etc. Suppose a student has just completed his study of materials in Force and Motion. He requests and receives question/problem book #3 from the proctor assigned to the terminal room.

Each book contains three separate banks of questions. One of the important security features built into EMIS is that the questions for the three banks are completely scrambled within the book. As the student skims the page, there is little liklihood that he will be able to separate the questions belonging to his bank from the others.

The student then logs in at any free terminal, takes part in a short dialogue with the computer in which he is asked to identify himself and the bank he wants, and specify whether he wishes a test or a drill. The computer appropriately selects the questions in a random fashion.

There are two important differences between the test and the drill. In the presentation of a drill, the student is informed immediately after typing his answer whether he was correct or not. In the test, the student moves from question to question without any feedback about his answer. The second difference is that scores made by students on drills are not recorded. Test scores are, of course, automatically recorded in the computer memory for later processing. The computer selects one of the five available versions for each question, displays the item number and keyword and then waits for the student's answer. At the conclusion of the test or drill, the computer prints out the student's score and informs him as to whether or not he has passed.

At this point, certain automatic procedural constraints upon the student come into play. If he has just completed a drill, he may take another one on the same bank or a previous one, but he is not permitted to proceed beyond the point unless he first takes the test for the current bank. If the run was a test and the student passed it he may proceed to the next bank for a drill or a test. If he failed the test, however, he is asked to report to his instructor for a procedural decision. He is not permitted a retest unless his instructor enters the proper command at the terminal. The instructor may override any of these automatic constraints at any time.

There are a number of additional features on the EMIS system. First the course author or the individual who writes the test items for a course has the opportunity to level the items by objectives, difficulty, and version. For example, specified sets of items are keyed to pertain to specific instructional objectives. The mastery of an objective can then be defined as a minimum number of items per objective, thus rendering mastery measurable.

Another feature is that the author may enter questions into a system by way of a simple card format which lays out all the decisions for him. Third, there is an optional weighted means scoring procedure which permits the assignment of more credit for the more difficult items and less credit for the easier items. Fourth, items are randomly selected from within item pools and levels of objectives.

A variety of reports for use by students, instructors, and administrators can be generated. These reports provide comprehensive records of individual student progress, analyses of individual performance for remediation, records of cumulative class progress, analyses of strengths and weaknesses in question categories, cumulative item analyses, and indication of the existance of trouble flags.

EMIS is a level II CMI operation which provides instructor support across a wide range of content areas.

Science - BIO/CMI. The second example of CMI in science education falls under the category of a non-traditionally organized science course. Incidentally, the term traditionally-organized was one which I first used as I did my thesis at Purdue University with Professor Postlewait on his Audio-Tutorial Systems laboratory. I had no trouble finding a name for the audio-tutorial systems but I did have a great deal of difficulty finding a name for the control group. It was somewhat traditional, classical, or whatever you wanted to call it, but the word traditional just did not seem appropriate so I employed the descriptor traditionally-organized class.

It may appear that I have selected this next example for the sake of Professor Postlewait who is here on the platform but this is not the case. I selected it because it happens to be in my opinion a good program. It is the program in freshman biology at Ohio State University which utilizes the Audio-Tutorial System as the main instructional format and a CMI system to provide the testing. The program is being conducted now by Dr. Roger Burnard and it was originally put together by Ben Meleca and Michael Allen.

An overview of this project is contained in report entitled "A Module for Computer Management of Modular Individualized Instruction." (Allen, Meleca, and Myers, 1973)

> "At Ohio State, an attempt is being made to incorporate individualized instructional philosophy into the design and development of a generalized computer management model; and further, to implement this model for the management of their introductory biology programs. Students will be offered an opportunity to progress through the course: by selecting their own rate of learning, by selecting areas of personal interest, with greater flexibility and options in decision making concerning what "I want to learn", gaining credit for the course whenever completed.
>
> Coursewriter III, Version II, for System 370, was used to implement the model. User modifications greatly expanded the flexibility of the language and allowed uncompromised realization of the management model. Various course materials are presented to students on-line who are prescribed for off-line use to help the student achieve mastery level learning.
>
> Inherent in our individualized learning programs are the following components:
>
> 1. Clearly specified acceptable learning outcomes.
>
> 2. Diagnostic testing of the learners initial state.
>
> 3. Accommodation of a variety of learning strategies through the use multi-media facilities for simplified correlation and documentation of data collected via the computer management system.
>
> The use of computer managed instruction (CMI) in the instructional strategy allows the authors the advantages of being able to collect, store, and retrieve a variety of data for systematic improvement and development of instructional programs. Although the first implementation of the model was made to insure the model's general adaptability to any content area at any level. The computer programs developed incorporate a "fill in the blanks" design for extremely simplified implementation." (p. 3)

The following is a description of the Ohio State biology CMI program (personal correspondence):

1. The content of the course is presented via the audio-tutorial method and the lecture, labwork, demonstrations, films, etc., are available to students for approximately 65 hours each week in the learning center. Students are free to spend as much time as they deem necessary to reach the desired objectives. Biology instructors are on duty at all times.

2. Each unit of study is developed around stated behavioral objectives all of which are made available to the student at the beginning of the term. Students are given a pretest at the beginning of the quarter over the objectives of the course and are given credit for units where they can demonstrate "mastery understanding." Students are then free to move immediately into subject areas they have not mastered and thus use their time more efficiently. Students are currently responsible for completing nine different units during the quarter.

3. All tests are taken at a Hazeltine 2000 CRT Computer Terminal at a time set by the students. The students can take a test over a unit of study as soon as they feel they have mastered the material. Test items are based on behavioral objectives and randomly generated from a large question bank. In addition, the behavioral objectives have been leveled into three sub-categories based on Bloom's taxonomy.

4. Students are given immediate feedback after each test item and a test score is automatically recorded at the end of the exam. Since every question is keyed to a behavioral objective, a hard copy description can be generated at the end of the exam, thus providing each student with a statement telling him what to do to correct his deficiencies. Tests are repeatable. When students feel they have corrected their deficiencies, they can return to the testing center and take another randomly generated test over the unit.

5. The result is that students continue to try harder and subsequently achieve a higher level than they might under a "traditional" testing situation. The student can demonstrate a greater understanding; thus, BIO/CMI does not spell gift - it spells opportunity.

6. Students can move through the course entirely at their own pace and here is the real area of benefit to students. We can provide them the course components as soon as the student is ready for them. A number of energetic and capable students have completed the entire course in two to three weeks and were then free to spend their time in other subject areas. Students can move through the courses independently of one another. A more gifted student is not slowed down by other students and students at the other end of the spectrum of ability and motivation can be served simultaneously and effectively.

7. Students have access to their course records each time they sit down at the computer terminal. Thus students are continually aware of their level of achievement throughout the quarter. The instructor also has continuous access to those performance records.

8. The BIO/CMI provides a mechanism for increasing meaningful student instructor interaction. Competent instructors are available in the Lab and the testing center on a regularly scheduled basis in an open door policy.

9. While the overall course enrollment is some 3500-4000 per quarter, student class size is kept relatively low - no more than 35 students per section.

10. Optional units can be made available to student who wish to do more in a particular subject area.

11. The stress of test taking is removed. Test results are, therefore, a more accurate evaluation of the student's understanding of course content. If the ability to function efficiently under stress is essential because the student is going into a high stress profession such as medicine and will be working in an emergency room, this expertise can, will, and should be developed in upper division programs. The removal of stress from test-taking has been accomplished without jeopardizing the accuracy of the evaluation of student performance.

How does it feel to be a student in biology at Ohio State? Suppose we look at an excerpt of an introductory pamphlet given to students in the program.

> You will not have to worry about taking mid-terms this quarter. Your test will be self-administered on the computer terminals in 52 Rightimier Hall. For each module, you will take a pretest. We recommend that you take this test without prior preparation and then use the information for your study plan. After the pretest, you will be given a list of the objectives in the guide that you have not mastered. Your next test on that module will be a criterion test. Once you have earned mastery, you may move on to the next module or you may keep working in the same module toward a higher grade. The computer will record your highest score for your grade. You will take one pretest on each assigned module and an unlimited number of criterion tests. You are free to take the test over any previously mastered module when you feel your understanding of the material has increased. You must keep the pace of student as listed on the syllabus for the course, at least one module of study per week. You may advance at a faster rate, but you should see your instructor if you fall behind. You should have mastered two modules by Friday of the third week of class, two more by Friday, the sixth week of class, and two more by Friday, the eighth week of class. If you fall behind and fail to meet these very minimal performance levels, it will be necessary to transfer you to a regular section in which your final course grade will be based on your performance on the two regularly scheduled mid-terms, two practical exams, three quizzes, and a final grade.

A summary of the BIO/CMI program at Ohio State reveals some interesting formation. (Allen, et al., 1973)

> "To accommodate the range and sequencing of subjects, student teacher scheduling, media software and hardware logistics, and mechanics of accommodating individual goals at individual paces, requires at least a system approach based on computerized technology (Lippert, 1971). The complexity of integration of several education idiologies has been carefully traced and the integration has been shown to be feasible, if the role of the instructor is really fine, and if the computer is used to govern the routine processes of testing and record keeping. More specifically, the instructor must assume the responsibility of the learning counselor. He must work with individual students to solve unique problems, represent a model of scholarly behavior, and encourage motivation to learn. Furthermore, he must cultivate a humanizing learning environment while helping students use performance feedback constructively" (page 13).

Non-Science - AIS. The project I would like to briefly describe now is the Air Force Advanced Instructional System or (AIS). AIS is directed by Joseph Yasutake and Marty Rockway at the Lowry Air Force Base in Denver, Colorado (Rockway and Yasutake, 1974.)

"The AIS is a prototype computer-based and multi-media system for the administration and management of individualized technical training on a large scale. The primary function of the AIS is to provide training and management for up to 2,100 students per day in four selected courses currently being taught at the Lowry Technical Training Center in Denver, Colorado. A secondary function of AIS is to serve as a research and development facility for the Air Force to evaluate the cost and training effectiveness of instructional innovations. The AIS is being developed through contract with McDonald Douglas Corporation. The contract is for approximately $10 million incrementally funded over a four-year period. The $10 million figure includes six sub-contracts let to business and universities.

The computer hardware is a CYBER 7314 with modified PLATO for terminals. The computer software is a language called CAMIL, which stands for Computer Assisted/Management Instructional Language, a high level language to provide CAI and CMI capabilities for the AIS. This is essentially a re-written version of the PLATO language developed at the University of Illinois.

The operational phases of the CMI capability have been divided into initial interim and long-term status. The initial development calls for test scoring, student data files, data collection and analysis, limited reports, student enrollment, and realtime interaction, and a mark sense scoring terminal. This is a terminal which feeds mark sense score sheets directly into the system. The interim capability includes the initial capability plus the first interaction of adaptive models including resource allocation, module assignment, student prescription, remedial assignments. Included also are extended reports and realtime interaction at the A terminals. These are the on-line PLATO terminals. The long-term development includes the initial and interim plus refinement of the adaptive models including adaptive testing, incentive management, student prescription, course completion prediction, and remedial assignments. Also included on the list are full reports, task inventory, course conversion, and field follow-up evaluation.

Although four courses have been chosen for implementation on the AIS system, one of them is of primary concern to science educators in that it deals with a precision measuring equipment course. It includes such things as calibration and use of test equipment, troubleshooting, etc. It is designed to be used with high aptitude students." (page 62).

AIS embodies some special military considerations which may or may not apply to college and university instruction. First, the students in the military are paid, housed and fed. To bring them from their field location to a central site for training requires an extra outlay of money. When one figures the cost of paying, housing, and feeding students in addition to their travel, the effectiveness of reducing the learning time can result in actual dollars. A number of projects including the AIS project seem to indicate about a 33% savings in learning time as a result of more efficient and effective instruction. Just how Universities will deal with this reduced learning time is not clear at this point. In fact, reduced learning time often causes problems for the instructor and administrator in the university in that a student may complete a course before a normal prescribed period of time has elapsed.

The second point is that these courses in AIS are essentially vocational education and hands-on, skill-oriented courses and permit the demonstration of the CMI system in a more vocational and less academic oriented application. The third point about military applications is the need for incremental pay-offs. That is, the system must show cost savings at certain periods in the operation and development for it to be adopted.

The AIS project also includes instructor training modules which model the AIS system, and author training modules. The distinction between instructor and author is that the instructor is one who conducts a course and the author is one who generates a course. One of the early problems at the AIS operation at Lowry occurred with instructors. Most military instructional organizations select their instructors on the basis of their platform performance in front of a group of students; the initial round of instructors that were brought in to work with the AIS system had been selected on that basis. Instead of fulfilling that role, however, they were asked to be facilitators or managers of the learning environment. A related observation from this example is a counter-argument to the dehumanization of the use of computers in education. It can be argued that there are a number of faculty members and instructors who hide behind large impersonal lectures to avoid direct individual and interpersonal contact with students. This is not surprising when one considers the well documented personality differences between scientists and those who work in the humanities. Of course, the complexities of humanizing or dehumanizing education transcend the simple examples and arguments that have been presented here.

A major goal of the AIS system is to provide a large scale CMI operation (Rockway and Yasutake, 1974).

> "There is considerable evidence that given certain specified conditions, each of the above innovations can be used individually to increase the cost effectiveness of instruction over that possible with traditional approaches. What has not been demonstrated is the optimal synthesis of current technology into a fully integrated system for the administration and management of individualized self-paced instruction on a large scale. . .Although much of the component technology to develop AIS is largely state of the art, the AIS itself is unique in a number of respects; first it will be the first attempt to integrate all the technology required for the cost effective implementation of individualized instruction on a large scale. Second, unlike most current systems which involve a commitment to a single or limited number of approaches such as programmed instruction, or CAI, the AIS will provide a capability for the utilization of several available methods and media. Third, the AIS contains within it the capacity for incorporating new instructional and management innovations as they become available. Fourth, inherent within the AIS is the capability for continuously evaluating and upgrading its own cost effectiveness and, finally, the AIS is being designed as a total system to perform all of the instructional system design, administration, and management functions required to conduct a large-scale training enterprise" (p. 237).

Non-Science - CAISMS. CAISMS stands for the Computer Assisted Study Management System which is run at the University of Illinois at Urbana on the PLATO CAI system.

CAISMS was designed to integrate books, computers, and live teachers in an effective manner. The system is intended for courses with large numbers of students and instructors such as introductory courses in community college, university, or military settings. The logistic problems associated with the multi-faceted instruction programs and large numbers of students and faculty were solved, in part, by using a CAI system for CMI purposes.

In the managed course, students are expected to acquire basic information concepts primarily from individual reading. Their attention to the material is maintained and the progress monitored by a previously developed and evaluated student management system. The system intermittently questions the student about what he is studying so as to maintain deep cognitive processing. In practice, the student signs on at a computer terminal and receives a four to eight page reading assignment. The student then leaves the terminal and studies the material in a nearby work space. He then signs on and receives a short quiz over the assignment just finished. Depending on quiz performance, the student is given a new assignment or told to review. A new assignment is the option provided if the student scored 75% or higher. Otherwise the student must retake the quiz following a seven-minute program delay which is intended to encourage careful study. The cycle starts again with the next assignment.

The CAISMS system was developed for a text-oriented lecture course format. The course is an economics course which meets in large lecture sections and in smaller recitation seminars at regularly scheduled intervals. Second, the psychological principle of deep processing was carefully built into the management component of the course. When students are given reading assignments the instructor can only hope the assignments are read. There is no way to guarantee that the readings do, indeed, occur. In the study management system, however, the readings must occur since students take frequent quizzes on the reading material. Unless they can pass these quizzes they do not proceed in the course. It is virtually impossible in a large group situation to insure that the students do complete the readings. This process of quizzing individuals on readings or materials that they have just studied on a regular and frequent basis is empirically supported by a number of research studies conducted over a span of 75 years.

If the student fails a study quiz he is locked out of the computer for a period of roughly 10 minutes or just about enough time for him to read the materials. This feature is designed to counter the tendency to continue to retake the quiz without bothering to complete the readings. When I visited the system about a year ago I talked to some of the students and found that some felt rather uncomfortable about this procedure. One student said, with a twinkle in her eye, that there were ways of getting around the system. Given a short time span and ready access to the readings, it is likely that the student will, indeed, proceed to the readings.

Anderson et al., (1974) conducted an experimental evaluation of the CAISMS. Two hundred twenty eight students who were enrolled in the course served as the subjects. One half of them were designated as the experimental group and the other half as a control. Both groups were required to complete the same activities with the exception that the experimental group was required to complete the study-management portion of the course. That is, they had to complete the readings and then complete the study quizzes successfully before they were permitted to take the regular and the final examination. The control students did not participate in the study-management section. It was found that in terms of course achievement the experimental group scored significantly higher than the control group on three of the four major course examinations, including the final examination.

Based upon scores from a standard University Course Attitude Questionnaire the experimental group's attitude was significantly more positive than that of the control group. Further analysis on attitudes revealed that the experimental treatment did not influence course attitude in small sections of classes, but it did facilitate the attitude for those students enrolled in larger class sections.

On the third criterion of dropout rate in the course, there was no significant difference between the two groups. Further analysis showed that in the CAISMS group there was no difference between those who dropped the course and those who did not drop the course. In the control group, however, there was a significant trend towards students with larger numbers of cumulative hours and low grade point average to drop the course. The method of analysis controlled for general ability.

Non-Science - ISS. One could not expect to hear a talk on computer-managed instruction without discussing some of the work being done at Penn State. Permit me to take a few moments and discuss what we call the Instructional Support System (ISS). ISS at Penn State is a form of level II CMI. If you will, it is interactive examination at a computer terminal with the data batch processed at a later time and reports generated for students and instructors during the evening hours.

The Computer Assisted Instruction Laboratory at The Pennsylvania State University has been in operation since 1964. Graduate and undergraduate courses are offered in both CMI modes and CAI modes. The operational system at the Laboratory is the interactive IBM 1500 series with the data being batch processed on a 370 series machine at the Computation Center. Penn State has both an interactive data processing system and a batch data processing system operating under ISS.

For example, Language Ed. 441, The Teaching of Children's Literature, utilizes the CMI system for measuring individual student competencies and basic knowledge in six separate areas of children's literature; these data are batch data processing for daily feedback and weekly progress report for all competencies, whether taught on- or off-line.

Organizations which train teachers have seriously looked at what is called the competency based teacher education (CBTE) movement. CBTE assumes that a specific competencies acquire and demonstrated by a teacher are more important and more predictive of a successful teacher than are a series of courses.

A particular course has the responsibility for developing numerous competencies in prospective teachers. Each prospective teacher then must be checked out for mastery of these competencies and has 30 students in a section, an instructor must deal with 360 individual skills. In the past the only performance indicators may have been a midterm and final examination score (60 pieces of data). Thus a competency based teacher education movement is creating serious problems in simple management of student competencies.

There are two forms of ISS presently in use at Penn State. In one form all of the testing is done on-line with interactive computer terminals. The data are then batch processed along with other course information supplied by the instructor. Subsequent individual student and instructor reports are generated on a regular basis with a 12 hour turnaround time. In the second format, students take paper and pencil tests using special mark-sense answer sheets. Data are read through special sheets into an Op-Scan 17 machine and read into a Texas Instrument Terminal which creates a cassette tape data bank. The cassette tape data bank is connected with the IBM system 370 which creates a bat file which then is processed on the ISS software. The output is generated and posted on the following day at the appropriate location.

There are many competencies in teacher training which cannot be assessed through paper and pencil examinations. The ability to create instructional objectives and the ability to generate and conduct a lesson in the classroom are skills which do not appear to be manageable by computer. These skills, however, are amenable to evaluation by a human observer who can break down the performance in terms of subskills and determine whether or not the student has demonstrated mastery of those individual sub-skills. This information can be coded onto the mark-sense form and is then sorted and merged with the total sets of data in batch mode.

Another unique and useful feature of the ISS is that it can provide detailed diagnostic and prescriptive feedback to students and instructor relative to a student's performance on objectives and subobjectives. For example, Language Ed. 441 has been divided into 7 modules with each module broken down into a number of objectives. In this particular course there are six sub-objectives for five of the modules, the remaining two modules having seven sub-objectives each. A number of test items have been created for each objective which are available to measurement by paper and pencil test evaluation. When a student takes his test on the computer he receives immediate feedback in the terms of the number of items, objectives, and modules correct. Further feedback is available when the printed copy of student progress reports are returned.

An individual student progress report includes a weekly listing of all of the modules and sub-objectives, lists the date in which the competency for each of the objectives was attempted, and the results. S/U is used to indicate performance on skills competencies. In the case of a paper and pencil test the date of the attempt the test, the score, and the ratio of the number of items correct to the total number of items on the test is printed. Another feature is the printing of the number of items a student got correct for each objective and the number of test items for that particular objective. The total test is then broken down into the sub-objectives and sub-scores. An individual can immediately determine whether he has passed each given objective and can use this information to further refine his study habits. Courses use one of two test generation systems. In one instance there are three alternate forms of the same test. When the student signs on he is randomly assigned to one of the three alternate forms. In the other course, the individual items are randomly selected for the student from within stratified pools.

One of the underlying assumptions of individualized instruction is the diagnostic-prescriptive process. The sophistication of the diagnostic-prescriptive process is primarily dependent upon the instructor since ISS has a mapping flexibility of large proportions and can accommodate the instructors. In operation the system administers a searching examination and prints a record of mastery or non-mastery for each objective of the test. If the student fails to meet the minimum criterion for any objective, a learning prescription is generated for that individual student. For example, the learning prescription for a certain objective reads as follows: "Descriptors missing. Write in where appropriate and return for evaluation." Another prescription has the following direction: "Unsuitable for designated age. Return with written justification for your suitability selection, change suitability, or turn in new selection for evaluation suitable for the age group specified."

Students are permitted multiple chances at the examinations until mastery has been met. Initially this had the detrimental effect of students returning time after time to take the test without spending time studying between testings. For example, one student during the first term of operation of this particular system retook a test forty-one times. This problem had also occurred in Anderson's work with CAISMS at the University of Illinois. The solution was to limit the number of times a student could attempt to demonstrate mastery (take a test) through a physical restriction or a grade reduction.

Dr. Singh (1974) has summarized the instructional support system as follows:

> "Computer managed instruction in the form of ISS at The Pennsylvania State University is operating efficiently and effectively. Both students and instructors who are dedicated to quality instruction have found ISS indispensible to quality individualized instruction.
>
> ISS is a system aimed to support individualized instruction. It has the flexibility to perform a variety of computational tasks either for evaluative variance as well as, individualized record keeping and varied feedback control. Hence while ISS has its origin in the College of Education which initially felt the need to implement a competency-based teacher education program, it is a system which is adaptable to forms of instruction an any area at any level of complexity" (p. 30).

Guided Learning Systems. I would now like to turn briefly to a level III CMI system which has recently been proposed for funding. When one is describing a proposed system, one's imagination and fancy can be let fly to the winds. So as not to let my fancy fly too far, I will try to constrain myself to wordings from the actual proposal itself.

A little background is in order. Pennsylvania State University is composed of twenty-one campuses. The main campus is at University Park, Pennsylvania and enrolls approximately thirty thousand students. The other campuses enroll approximately nineteen thousand undergraduate students, the majority at the freshman and sophomore level. Each campus offers a similar basic freshman/sophomore curriculum and when students come to University Park as juniors, they are assumed to have had similar backgrounds. The quality of instruction varies depending on the facilities, the resources, and the instructors available at all campuses. So there is a need to provide a certain quality and uniformity of curricular offering.

The second factor impinging on this particular proposal was a designation of the Allentown Campus of The Pennsylvania State University to be the educational innovative leader in the Commonwealth Campus System. A new building is being constructed there; it was decided to implement the CMI format there and capitalize on the momentum for change already in operation.

GLS Philosophy. Tł ınique opportunity to establish a prototype lower division undergradua instruction unit at Allentown has encouraged

the faculty at Penn State to design a model instructional management and delivery system. This new plan, called the Guided Learning System (GLS), is a key element in restructing the undergraduate learning environment at Penn State in order to meet the pressing higher education needs.

Basically GLS is an operating system for information management and retrieval. The information to be managed and retrieved deals with instructional elements such as subject matter questions, corresponding correct and incorrect answers, instructional prescriptions, student performances, and instructor evaluations. Operation of the model depends upon a creative interaction among students, faculty, instructional materials, and computer terminals.

The model is called guided because students are provided with guidance so that the study procedures they follow are adapted to their particular needs and characteristics. By employing a diagnostic-prescriptive strategy the system guides the learners through a series of choices or options based upon the students past history in instruction. GLS emphasizes learning by focusing on the student's active and frequent demonstration of the achievement of instructional objectives. In contrast the conventional undergraduate instruction most often emphasizes teaching activities and relatively infrequent appraisal to see whether the teaching has resulted in the student learning. GLS is a system because it has a number of interacting components designed to maximize self-directed and self-paced achievement on the part of students with different backgrounds, abilities, and interests.

When it is fully operative, approximately sixty percent of the student coursework at the Allentown Campus will be delivered by GLS. The remaining forty percent of the student's courses will follow conventional instructional procedures. The typically high enrollment in science and technology courses have been chosen for initial development. The course adaptation effort is projected over a two year period and will take place at an Allentown developmental center.

How GLS is Expected to Function in an Undergraduate Environment. The standard plan for GLS envisions a student acquiring knowledge, concepts, and skills from separate lessons and instructions by means of self-paced study. When the student believes he has mastered the material he goes immediately to one of several computer terminals on campus and is given, without any intervention by the instructor, a searching examination keyed to the objectives of the lesson. In a typical three credit course we expect that there will be approximately eight modules with an average of six lessons per module. These modules will be independent to the extent possible.

Media for self-paced study include videotapes, audiotapes, printed materials of all types, film strips, motion picture segments, instructor presentations, and laboratory demonstrations. In planning and implementing the program of instruction at Allentown, it will be necessary for the faculty who act as course designers to prepare initially only a small portion of the material for student use. Hopefully, in most subject areas, there will be chunks of curriculum that can be obtained from a variety of outside sources. The course designers will however, have to build stored computer program materials (tests, diagnostic logic, student options, and prescriptions) for every lesson corporated into the curriculum whether it is homemade or acquired from another source.

How GLS is Related to Individualized Instruction. The proposed GLS can properly be classified as personalized or adaptive in several ways. First, the self-study provisions provide several individual pacing or rate tailoring to the student which is not characteristic of conventional undergraduate mass education. Although Penn State's ten week term system and rules regarding incomplete studies pose some constraints on student's rate of performance, there is none the less a great deal of room for a student's individual study style to operate.

Second, we propose to give students the maximum amount of instructor and peer support for their achievement efforts. For example, bi-weekly progress reports will be provided to the instructor of a GLS course, making it a simple matter to monitor individuals to perform.

Similarly students will receive cumulative course records detailing performance in individual GLS courses, thereby fostering increase student responsibility and initiative. Each group of 20 student stations will be equipped with a medium speed printer giving both students and instructors access to appropriate cumulative achievement records.

GLS is designed to provide students with four adaptive learning tracks. We have labeled these tracks Alpha, Beta, Gamma, or Delta level in order to avoid the potentially misleading connotations of more descriptive labels such as fast, normal, remedial, etc. Alpha level is designed for the extremely able student who can meet the achievement criterion on a diagnostic pretest without extended formal instruction. Beta level instruction is mainline self-paced instruction organized into study lessons. Although students will study most lessons individually, in some instances they may take place in small groups or in the class as a whole according to the needs of the subject matter and the instructor. Students will read, experiment, calculate, etc. Before proceeding from one lesson to the next they will demonstrate mastery of what has been studied.

Gamma level is remedial for those students who cannot reach the criterion on the first attempt in Beta level instruction. In Gamma instruction the number of examples may be increased and study guides may be provided to supplement Beta level material. Gamma level instruction the number of examples may be increased and study guides may be provided to supplement Beta level material. Gamma level instruction will typically take the students somewhat longer to complete, because of the fuller explanations and added exercises and examples. The Delta level of instruction is reserved for those students who cannot meet the criterion after receiving Gamma instruction. At Delta level the instructor obtains performance data from the student's stored records, interviews the student and attempts to either tutor the student or to provide a source of new material through self-study. When a student at Delta level instruction has reached a satisfactory level of achievement, he is readmitted into the program at an appropriate level for the next lesson. For the whole system to be cost effective relatively few students, (i.e. less than 5%) should be functioning at Delta level at any one time. If that is not the case, too much faculty time will be consumed with individual tutoring of the least competent students. In summary, Alpha, Beta, and Gamma level instruction can be provided by the CMI system. Delta level instruction takes the point of view that the system cannot accommodate all students and certain situations must be relegated to the expertise and flexibility of an individual instructor.

The Role of Faculty in GLS. The faculty member responsible for GLS courses on a day-to-day basis is not involved in radically different or novel experiences. GLS instructors will monitor student progress, evaluate student performance, choose or construct classwork materials, and help individual students who are having difficulty. On some occasions they may give lectures or lead group discussions. The relative mix of these traditional instructor activities does however, change with the adoption of GLS. Because student learning is self-paced instead of group-paced, more time is spent by the instructor on individually oriented tasks rather than on group activities.

The task of the teacher in evaluating the overall achievement of students becomes somewhat simpler with detailed records of student performance on each lesson at hand in the form of computer printed reports. Competition among students for some fixed percentage of high marks should be replaced by increased motivation on the part of each student to measure up to a given standard of competence of mastery. Because learning is an individual and personal process it has always seemed an anomaly in higher education that evaluation of a student's achievement depends in many classes on the performance of other students, thus emphasizing competition rather than mastery as the basis on which grades are assigned. The assignment of grades however, remains the prerogative of the individual faculty member.

Whatever criteria are employed, GLS will provide the instructor with more reliable, well organized information about student performance than is typically available. In some situations the student rate of acquisition of new knowledge may be an important criterion. In other situations, rate may not be crucial. The instructor will thus be free to develop his own rationale for assessing student performance at assigning marks.

I would like to make three additional points about the GLS model. First, individual instructors can rather easily modify a given module if a CMI system with communication across terminals is available. This means that instructors at various campus sites can communicate information to one another rather readily about a particular course, a particular module, or a particular lesson in terms of its development or utilization.

The next point is that students can freely move between the Alpha, Beta, Gamma, and Delta levels of instruction without being locked into a fixed track system. A chief reason for a fixed tracking system in which a student finds himself rigidily locked is the lack of flexibility in frequent testing and availability of learning options. With GLS and its frequent testing it is anticipated that student performance can be monitored quite regularly and thus the decision to move a student from one level to another can be easily handled.

Finally the effectiveness of self-paced CMI has been demonstrated repeatedly in projects at numerous sites. These demonstrations have had limited impact on higher education generally because they have remained at the demonstration level. What seems to be needed at this point is not just another demonstration but a large scale, broad base commitment to systematic implementation. Penn State proves to be an almost setting in which to undertake the necessary implementation. It is the thirteenth largest University in the country with continuing enrollment increases and impressive human and material resources. With regard to the use of computers in education, it has been in the forefront for over a decade. At the Allentown Campus, it is prepared to establish GLS as an innovative restructured undergraduate environment and to generalize the system that emerges to all the other Commonwealth Campuses. The potential for impacting on higher education throughout the United States is enormous. Thus, although Allentown Campus effort may be properly regarded as a prototype the probability is that it will be copied and not just be admired.

We have examined computer-managed instruction and taken a very brief look at some of the projects which use CMI both science and nonscience military university, both real and projected. Let us now examine some topics of interest related to development of CMI Systems.

Characteristics of the Academic Environment for CMI Design and Operation

The experience of numerous CMI developers around the nation has resulted in a set of guidelines for those who would implement a CMI system. Allan (1974) has provided a comprehensive list of characteristics that one needs to consider when designing CMI. I will draw upon his basic list and supplement and expand on specific topics.

Generalizability. Potential CMI developers should focus on generalized models to fit existing curriculum rather than to develop highly specialized applications which call for unique CMI developmental efforts. Three areas come to mind under this general topic. First, CMI has been demonstrated to be useful in a variety of courses. Such course formats as lecture, lecture demonstration, lecture recitation, independent study, laboratory component courses and others have shown to be amenable to CMI. This is demonstrated in one setting at the AIS operation at Lowry Air Force Base and EMIS at NYIT. In AIS, three courses are presently in operation. One is clerical in nature and another is highly technical with the use of precision equipment. At the University of Illinois, Tom Anderson's project deals with a lecture recitation course typical of what one finds in large University settings.

Secondly, CMI should be useable in a variety of assessment situations such as multiple choice and the short answer test. In addition, many CMI systems are developing complex answer processing capability. Obviously the more complex the response of the student in answering a question, the more chance there is for making a syntax error. When one limits student answers to three lines of typed text, it is possible to obtain a fairly reasonable match between student input and the kind of information stored in the CMI system. Another category under testing situations is problem solving and procedural techniques. Newer computer programs and natural language assemblers permit hypothesis testing and problem-solving exercises to be evaluated either in a calculation or a noncalculation mode. And finally, one can easily merge in a generalized CMI situation results of offline evaluations; that is, evaluations made by an instructor and then coded into the system to match the data.

The third category is that a variety of instructional strategies can be incorporated with CMI.

Adaptability. A second major point is that a CMI system can be adapted to a changing educational environment. Indeed, one can raise the question of whether one should use CMI to supplement or lead the change process. One thing is certain: A change in the instruction is likely to change the system.

One area of concern in higher education today is adaptability to more adequately serve the new clientele, the new brand of student who is and will be demanding more and more from education. Included in this clientele are such groups as veterans, adult learners, the aged, the fully employed, the housewife, minorities, and so forth. The new clientele was clearly in mind as the GLS model was formulated.

Interface Between Components. The interface between the instructor, the system, and the student is extremely important. The system must not restrict the instructors' talents and it must be adapted to his needs. One pressing problem is the proper use of the instructors' time previously devoted to preparing and delivering lectures and grading papers. Obviously, he will continue to do some of these things but the emphasis will be shifted.

One fear is that the instructor will be required to spend a great deal of his time with the less than capable student, the one who falls out of the bottom of the system so to speak. In the GLS model this would be those students who are qualified by virtue of their performance in the class for Delta level instruction. It is apparent that if an instructor is freed from numerous clerical classroom functions in order to be able to provide remedial instruction to sometimes less capable, less motivated individuals, one can question whether the instructor is being rewarded or punished. However, the other side of the coin presents a quite different picture. The Alpha level student who proceeds quite rapidly through the instruction and comes out in the other end well prepared is qualified for in-depth study. During this time the instructor and students can get together and more thoroughly investigate various projects or subject matter applications. While there is opportunity to work with remedial students there is also the opportunity to work with the advanced students. It will be the instructor who decides in what direction his efforts will take him. It is common knowledge that working with more able and highly motivated students can be a pleasurable experience. One may have to consider special alternatives to avoid the undue emphasis on the higher ability student at the expense of the less able student.

Faculty Dependent. The fourth point relates to the availability of faculty and the dependence of the system on the faculty. To what extent can the system run without the instructor? Here we come to the age old problem whose solution is inextricably intertwined with instructor ego. Can one design an instructional strategy or instructional module to such a high degree that it can function by itself? Professor Postlethwaite on the platform has related numerous times how in the early developmental efforts of his Audio-Tutorial Systems the numbers of students who attended the lectures decreased exponentially during a semester. We at Penn State have had the same experiences in the sense of offering complete courses by CAI with optional help and supplementary sessions. Students apparently did not feel a need to attend these optional sections. One could hypothesize that the students did not like to attend optional sessions because they were in some way unpleasant. Rober Mager, who deals with behavioral objectives and other areas of instructional systems once observed that things that are surrounded by unpleasantness are not surrounded by people. This hypothesis is not really held up in this particular case because by most student ratings, the instructors were quite popular and effective in the classroom. It just turned out that the instructional materials which they created for the computer were exceptionally well done and sufficient.

Range of Instructional Environments. CMI systems can support a wide variety of instructional environments from teacher-centered to learner-centered (i.e., environments which range from lecture to independent study format). At this point I disagree with Michael Allen who indicates that CMI can only support a learner-centered instructional environment. He is correct however, if by a learner-centered environment he means one in which the emphasis is placed upon what the student can do as a result of the instruction rather than placing emphasis on what the instructor does for the student.

Innovation and Workload. Innovation is extremely hard work. The development of instructional objectives, stratifying of learner hierarchies within a subject matter domain, specification of complex testing strategies, and acquisition of instructional resources may be an unrealistic barrier to developing a CMI System. I see this as a serious detriment to the spread to CMI systems. Although it is not an insurmountable task to develop a CMI system and the associated instructional materials, our experience is that it is quite a complex undertaking to develop a high quality CMI system and a high quality set of associated instructional materials. One appropriate suggestion is to utilize existing resources by redefining and modifying existing curriculum materials into self-contained modular formats. A second alternative is to identify a source that will supply the money to acquire or develop the materials and system.

Subject Matter Confidence. Both the instructor and course designer need a high degree of confidence and variability in subject matter competence because as students progress at individual rates in a CMI operation they begin to spread out. In a matter of days some students are quite far removed from other students. To the extent that these students have individual questions about the subject matter (and they will) one has to be able to deal with questions that range from introductory to terminal concepts of the course, often in the time span of one day. This can involve a tremendous mental shift of gears for an instructor. Essentially he has to be capable at going 30 or 40 different directions, change directions on a dime, and go off in another direction very quickly. This does a great deal to one's concept of the structure of the curriculum, the organization of the way its presented, and the sequence in which it is presented.

System Restraints. Language and programming restraints can be insurmountable at times. Without a free hand the instructor does not have the necessary control over the system as it develops and operates. This lack of control can be extremely frustrating. For example, IBM's Coursewriter II and III are not difficult languages but the course authors we deal with are primarily educationally oriented individuals who are not well versed in computer logic and flow. This results in a need for a good deal of instruction.

At Penn State we have solved this problem through a pre-processor called TACL. The TACL language is an intermediate step between human natural language and a complex computer language. Most individuals can undertake a three to four hour block of instruction in TACL and author materials on specialized forms. Authors simply indicate the content of the instruction and the structural logic on these forms.

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Media for self-paced study include videotapes, audiotapes, printed materials of all types, film strips, motion picture segments, instructor presentations, and laboratory demonstrations. In planning and implementing the program of instruction at Allentown, it will be necessary for the faculty who act as course designers to prepare initially only a small portion of the material for student use. Hopefully, in most subject areas, there will be chunks of curriculum that can be obtained from a variety of outside sources. The course designers will however, have to build stored computer program materials (tests, diagnostic logic, student options, and prescriptions) for every lesson corporated into the curriculum whether it is homemade or acquired from another source.

How GLS is Related to Individualized Instruction. The proposed GLS can properly be classified as personalized or adaptive in several ways. First, the self-study provisions provide several individual pacing or rate tailoring to the student which is not characteristic of conventional undergraduate mass education. Although Penn State's ten week term system and rules regarding incomplete studies pose some constraints on student's rate of performance, there is none the less a great deal of room for a student's individual study style to operate.

Second, we propose to give students the maximum amount of instructor and peer support for their achievement efforts. For example, bi-weekly progress reports will be provided to the instructor of a GLS course, making it a simple matter to monitor individuals to perform.

Similarly students will receive cumulative course records detailing performance in individual GLS courses, thereby fostering increase student responsibility and initiative. Each group of 20 student stations will be equipped with a medium speed printer giving both students and instructors access to appropriate cumulative achievement records.

GLS is designed to provide students with four adaptive learning tracks. We have labeled these tracks Alpha, Beta, Gamma, or Delta level in order to avoid the potentially misleading connotations of more descriptive labels such as fast, normal, remedial, etc. Alpha level is designed for the extremely able student who can meet the achievement criterion on a diagnostic pretest without extended formal instruction. Beta level instruction is mainline self-paced instruction organized into study lessons. Although students will study most lessons individually, in some instances they may take place in small groups or in the class as a whole according to the needs of the subject matter and the instructor. Students will read, experiment, calculate, etc. Before proceeding from one lesson to the next they will demonstrate mastery of what has been studied.

Gamma level is remedial for those students who cannot reach the criterion on the first attempt in Beta level instruction. In Gamma instruction the number of examples may be increased and study guides may be provided to supplement Beta level material. Gamma level instruction the number of examples may be increased and study guides may be provided to supplement Beta level material. Gamma level instruction will typically take the students somewhat longer to complete, because of the fuller explanations and added exercises and examples. The Delta level of instruction is reserved for those students who cannot meet the criterion after receiving Gamma instruction. At Delta level the instructor obtains performance data from the student's stored records, interviews the student and attempts to either tutor the student or to provide a source of new material through self-study. When a student at Delta level instruction has reached a satisfactory level of achievement, he is readmitted into the program at an appropriate level for the next lesson. For the whole system to be cost effective relatively few students, (i.e. less than 5%) should be functioning at Delta level at any one time. If that is not the case, too much faculty time will be consumed with individual tutoring of the least competent students. In summary, Alpha, Beta, and Gamma level instruction can be provided by the CMI system. Delta level instruction takes the point of view that the system cannot accommodate all students and certain situations must be relegated to the expertise and flexibility of an individual instructor.

The Role of Faculty in GLS. The faculty member responsible for GLS courses on a day-to-day basis is not involved in radically different or novel experiences. GLS instructors will monitor student progress, evaluate student performance, choose or construct classwork materials, and help individual students who are having difficulty. On some occasions they may give lectures or lead group discussions. The relative mix of these traditional instructor activities does however, change with the adoption of GLS. Because student learning is self-paced instead of group-paced, more time is spent by the instructor on individually oriented tasks rather than on group activities.

The task of the teacher in evaluating the overall achievement of students becomes somewhat simpler with detailed records of student performance on each lesson at hand in the form of computer printed reports. Competition among students for some fixed percentage of high marks should be replaced by increased motivation on the part of each student to measure up to a given standard of competence of mastery. Because learning is an individual and personal process it has always seemed an anomaly in higher education that evaluation of a student's achievement depends in many classes on the performance of other students, thus emphasizing competition rather than mastery as the basis on which grades are assigned. The assignment of grades however, remains the prerogative of the individual faculty member.

Whatever criteria are employed, GLS will provide the instructor with more reliable, well organized information about student performance than is typically available. In some situations the student rate of acquisition of new knowledge may be an important criterion. In other situations, rate may not be crucial. The instructor will thus be free to develop his own rationale for assessing student performance at assigning marks.

I would like to make three additional points about the GLS model. First, individual instructors can rather easily modify a given module if a CMI system with communication across terminals is available. This means that instructors at various campus sites can communicate information to one another rather readily about a particular course, a particular module, or a particular lesson in terms of its development or utilization.

The next point is that students can freely move between the Alpha, Beta, Gamma, and Delta levels of instruction without being locked into a fixed track system. A chief reason for a fixed tracking system in which a student finds himself rigidily locked is the lack of flexibility in frequent testing and availability of learning options. With GLS and its frequent testing it is anticipated that student performance can be monitored quite regularly and thus the decision to move a student from one level to another can be easily handled.

Finally the effectiveness of self-paced CMI has been demonstrated repeatedly in projects at numerous sites. These demonstrations have had limited impact on higher education generally because they have remained at the demonstration level. What seems to be needed at this point is not just another demonstration but a large scale, broad base commitment to systematic implementation. Penn State proves to be an almost setting in which to undertake the necessary implementation. It is the thirteenth largest University in the country with continuing enrollment increases and impressive human and material resources. With regard to the use of computers in education, it has been in the forefront for over a decade. At the Allentown Campus, it is prepared to establish GLS as an innovative restructured undergraduate environment and to generalize the system that emerges to all the other Commonwealth Campuses. The potential for impacting on higher education throughout the United States is enormous. Thus, although Allentown Campus effort may be properly regarded as a prototype the probability is that it will be copied and not just be admired.

We have examined computer-managed instruction and taken a very brief look at some of the projects which use CMI both science and non-science military university, both real and projected. Let us now examine some topics of interest related to development of CMI Systems.

Characteristics of the Academic Environment for CMI Design and Operation

The experience of numerous CMI developers around the nation has resulted in a set of guidelines for those who would implement a CMI system. Allan (1974) has provided a comprehensive list of characteristics that one needs to consider when designing CMI. I will draw upon his basic list and supplement and expand on specific topics.

Generalizability. Potential CMI developers should focus on generalized models to fit existing curriculum rather than to develop highly specialized applications which call for unique CMI developmental efforts. Three areas come to mind under this general topic. First, CMI has been demonstrated to be useful in a variety of courses. Such course formats as lecture, lecture demonstration, lecture recitation, independent study, laboratory component courses and others have shown to be amenable to CMI. This is demonstrated in one setting at the AIS operation at Lowry Air Force Base and EMIS at NYIT. In AIS, three courses are presently in operation. One is clerical in nature and another is highly technical with the use of precision equipment. At the University of Illinois, Tom Anderson's project deals with a lecture recitation course typical of what one finds in large University settings.

Secondly, CMI should be useable in a variety of assessment situations such as multiple choice and the short answer test. In addition, many CMI systems are developing complex answer processing capability. Obviously the more complex the response of the student in answering a question, the more chance there is for making a syntax error. When one limits student answers to three lines of typed text, it is possible to obtain a fairly reasonable match between student input and the kind of information stored in the CMI system. Another category under testing situations is problem solving and procedural techniques. Newer computer programs and natural language assemblers permit hypothesis testing and problem-solving exercises to be evaluated either in a calculation or a noncalculation mode. And finally, one can easily merge in a generalized CMI situation results of offline evaluations; that is, evaluations made by an instructor and then coded into the system to match the data.

The third category is that a variety of instructional strategies can be incorporated with CMI.

Adaptability. A second major point is that a CMI system can be adapted to a changing educational environment. Indeed, one can raise the question of whether one should use CMI to supplement or lead the change process. One thing is certain: A change in the instruction is likely to change the system.

One area of concern in higher education today is adaptability to more adequately serve the new clientele, the new brand of student who is and will be demanding more and more from education. Included in this clientele are such groups as veterans, adult learners, the aged, the fully employed, the housewife, minorities, and so forth. The new clientele was clearly in mind as the GLS model was formulated.

Interface Between Components. The interface between the instructor, the system, and the student is extremely important. The system must not restrict the instructors' talents and it must be adapted to his needs. One pressing problem is the proper use of the instructors' time previously devoted to preparing and delivering lectures and grading papers. Obviously, he will continue to do some of these things but the emphasis will be shifted.

One fear is that the instructor will be required to spend a great deal of his time with the less than capable student, the one who falls out of the bottom of the system so to speak. In the GLS model this would be those students who are qualified by virtue of their performance in the class for Delta level instruction. It is apparent that if an instructor is freed from numerous clerical classroom functions in order to be able to provide remedial instruction to sometimes less capable, less motivated individuals, one can question whether the instructor is being rewarded or punished. However, the other side of the coin presents a quite different picture. The Alpha level student who proceeds quite rapidly through the instruction and comes out in the other end well prepared is qualified for in-depth study. During this time the instructor and students can get together and more thoroughly investigate various projects or subject matter applications. While there is opportunity to work with remedial students there is also the opportunity to work with the advanced students. It will be the instructor who decides in what direction his efforts will take him. It is common knowledge that working with more able and highly motivated students can be a pleasurable experience. One may have to consider special alternatives to avoid the undue emphasis on the higher ability student at the expense of the less able student.

Faculty Dependent. The fourth point relates to the availability of faculty and the dependence of the system on the faculty. To what extent can the system run without the instructor? Here we come to the age old problem whose solution is inextricably intertwined with instructor ego. Can one design an instructional strategy or instructional module to such a high degree that it can function by itself? Professor Postlethwaite on the platform has related numerous times how in the early developmental efforts of his Audio-Tutorial Systems the numbers of students who attended the lectures decreased exponentially during a semester. We at Penn State have had the same experiences in the sense of offering complete courses by CAI with optional help and supplementary sessions. Students apparently did not feel a need to attend these optional sections. One could hypothesize that the students did not like to attend optional sessions because they were in some way unpleasant. Rober Mager, who deals with behavioral objectives and other areas of instructional systems once observed that things that are surrounded by unpleasantness are not surrounded by people. This hypothesis is not really held up in this particular case because by most student ratings, the instructors were quite popular and effective in the classroom. It just turned out that the instructional materials which they created for the computer were exceptionally well done and sufficient.

Range of Instructional Environments. CMI systems can support a wide variety of instructional environments from teacher-centered to learner-centered (i.e., environments which range from lecture to independent study format). At this point I disagree with Michael Allen who indicates that CMI can only support a learner-centered instructional environment. He is correct however, if by a learner-centered environment he means one in which the emphasis is placed upon what the student can do as a result of the instruction rather than placing emphasis on what the instructor does for the student.

Innovation and Workload. Innovation is extremely hard work. The development of instructional objectives, stratifying of learner hierarchies within a subject matter domain, specification of complex testing strategies, and acquisition of instructional resources may be an unrealistic barrier to developing a CMI System. I see this as a serious detriment to the spread to CMI systems. Although it is not an insurmountable task to develop a CMI system and the associated instructional materials, our experience is that it is quite a complex undertaking to develop a high quality CMI system and a high quality set of associated instructional materials. One appropriate suggestion is to utilize existing resources by redefining and modifying existing curriculum materials into self-contained modular formats. A second alternative is to identify a source that will supply the money to acquire or develop the materials and system.

Subject Matter Confidence. Both the instructor and course designer need a high degree of confidence and variability in subject matter competence because as students progress at individual rates in a CMI operation they begin to spread out. In a matter of days some students are quite far removed from other students. To the extent that these students have individual questions about the subject matter (and they will) one has to be able to deal with questions that range from introductory to terminal concepts of the course, often in the time span of one day. This can involve a tremendous mental shift of gears for an instructor. Essentially he has to be capable at going 30 or 40 different directions, change directions on a dime, and go off in another direction very quickly. This does a great deal to one's concept of the structure of the curriculum, the organization of the way its presented, and the sequence in which it is presented.

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