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ABSTRACT

Using the expertise of faculty members of various departments, the University of Texas at Austin has initiated a four-year, two million dollar project, called C-BE, to examine the capacity of computer-assisted instruction (CIA) to improve teaching in the sciences and in engineering. The computer can assist the instructor by doing grading, bookkeeping, experiment monitoring, basic instruction, simulations, and data processing. When the instructor supplies a list of behavioral objectives, achievement measurement standards, and technical limitations, the systems analyst can then design the computer materials necessary to meet the instructor's requirements. The goals of Project C-BE are to quantitatively demonstrate the effect of CAI on the effectiveness of college teaching and to examine the relative costs. The computerized courses that are being designed could potentially be shared with other institutions. (EMH)

NEWS RELEASE TO ALL MEDIA AND WIRE SERVICES

A major problem that society faces is the need for improvement in education at all levels. Confronted with limited resources and the burgeoning demands of an expanding student population, Drs. John J. Allan and J. J. Lagowski are Co-Directing a project with some of their University of Texas at Austin colleagues to explore the use of computer-based instructional techniques in undergraduate education. The four-year project (Project C-BE), funded by the National Science Foundation and The University of Texas at Austin, represents a coordinated effort of the faculty of The University of Texas at Austin. The first year budget is $430,000, with a four-year budget of almost two million dollars.

The expertise of faculty members in various departments and colleges will be employed to develop and evaluate innovative computer-based undergraduate curriculum materials to improve the instructional processes in their respective disciplines. The project encompasses such subject areas as chemical, civil, mechanical, petroleum, electrical and aerospace engineering; chemistry; zoology; physics; psychology; economics; and sociology.

It has been suggested that the key to the individualization of mass instruction lies within a computer-based environment. This project is designed to develop efficient methods of implementing computer-based instructional techniques in a wide spectrum of disciplines, to evaluate the pedagogical and economic impact of such techniques, and to gather information on the factors associated with the transferability of the materials developed to other educational environments.

Computer-based instructional techniques are aimed primarily at assisting the instructor in meeting the growing demands of large classes being taught more and more sophisticated materials. This is accomplished by interfacing the student to remedial, tutorial, laboratory, design, etc, material using information processing, thus, leading to increased academic cost effectiveness and quality of instruction. In many subjects, for instance, there is a body of information that must be learned by the student, but which requires very little teaching by the instructor. It is one goal of computer-based teaching techniques to shift the onus for learning such material onto the student, thereby permitting the instructor more time for teaching and ultimately increasing teaching effectiveness in the classroom.

Computer-based educational methods are intended to extend and supplement the instructor, not replace him. In some cases, using a socratic-type environment, a student can interact with the computer using a television-type console and proceed through material at his own speed. Under such conditions each student is essentially engaged on an individual basis with an "instructor" who is specifically attuned to his background, rate of learning, and level of interest in the subject. Indeed, each module can be the product of one or many minds. Thus, each student in a large class has an opportunity to interact intimately with the best minds on the subject -- a situation which does not usually occur at present. Using such techniques, a form of self-paced instruction can be created permitting more flexibility in the present educational system. In other cases, small computers will be employed to relieve students of mundane, dangerous or complex laboratory tasks. It is the goal of an educational environment to teach principles, concepts and techniques most effectively.

It is planned to blend the best of the traditional teaching techniques -- drill, practice, and tutorial concepts -- with innovative computer-based methods. The techniques and materials developed will become an integral part of the normal curriculum.

GOALS OF THE PROJECT

Listed below are the four (4) objectives of our research as NSF views the effort.

I. IDENTIFY COMPUTER-BASED CONCEPTS THAT ARE COMMON AMONG SEVERAL DISCIPLINES

With reference to reactive terminals, computer graphics, or laboratory data acquisition--identify what concepts are common among several disciplines in either content, approach or technique.

II. DEVELOP EVALUATION PROCEDURES FOR THIS TYPE EFFORT

Develop procedures for evaluating the pedagogical and economic effectiveness and potential of computer-based techniques at the module, course, university, and national levels.

III. IDENTIFY THE ELEMENTS OF TRANSFERABILITY

Identify the elements of the effort that are critical to transferring successful educational packages, employing these techniques, from one institution to another.

IV. DEVELOP A FISCAL MODEL

Develop a fiscal model so that administrators may view these techniques from the standpoints of investment, operating expenses, comparative effectiveness.

Planning for an undergraduate level computer-based science education system that will be responsive to society's needs in the 1970's

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INTRODUCTION

The purpose of this paper is to discuss the planning of an undergraduate level computer-based educational system for the sciences and engineering that will be responsive to society's needs during the 1970's. Considerable curriculum development research is taking place in many institutions for the purpose of increasing the effectiveness of student learning. Despite the efforts under way, only limited amounts of course matter using computer-based techniques are available within the sciences and engineering.

Planning for a frontal attack to achieve increased teaching effectiveness was undertaken by the faculty of The University of Texas at Austin. This paper presents the essence of these faculty efforts.

An incisive analysis of the state of the art with regard to the impact of technology on the educational process is contained in the report "To Improve Learning" generated by the Commission on Instructional Technology and published by the U.S. Government Printing Office, March, 1970.[1] The focus is on the potential use of technology to improve learning from pre-school to graduate school. The goals stated in the above report are (1) to foster, plan, and coordinate vast improvements in the quality of education through the application of new techniques which are feasible in educational technology, and (2) to monitor and coordinate educational resources.

AN OVERVIEW OF COMPUTER-BASED TEACHING SYSTEMS

Until recently, interest in using machine-augmented instruction has been centered primarily on research in the learning processes and/or on the design of hardware and software.

Digital computer systems have now been developed to the point where it is feasible to employ them with relatively large groups of students. As a result, defining the problems involved in the implementation of computer-based teaching techniques to *supplement* classical instructional methods for large classes has become a most important consideration. Whether the classes are large or small, colleges and universities are faced with presenting increasingly sophisticated concepts to continually expanding numbers of students. Available teaching facilities, both human and technical, are increasing at a less rapid rate than the student population. Typically, the logistics of teaching science and engineering courses becomes a matter of meeting these growing demands by expanding the size of enrollments in lectures and laboratory sections.

It is now apparent that we can no longer afford the luxury of employing teachers in non-teaching functions whether on the permanent staff or as teaching assistants. Many chores such as grading and record keeping as well as certain remedial or tutorial functions do not really require the active participation of a teacher, yet it is the person hired as a teacher who performs these tasks. Much of this has been said before in various contexts, however, it should be possible to solve some of these problems using computer techniques. In many subjects, there is a body of information that must be *learned* by the student but which requires very little *teaching* by the instructor. Successful methods must be found to shift the onus for learning this type of material onto the student thereby premitting the instructor more time for teaching. Thus, computer techniques should be treated as resources to be drawn upon by the instructor as he deems necessary, much the same as he does with books.

Basically, the application of computer techniques is *supplemental to,* rather than a *supplantation of,* the human teacher. The average instructor who has had little or no experience with computers may be awed by the way the subject matter of a good instructional module can motivate a student. If the program designer has been imaginative and has a mastery of *both* his subject and the vagaries of programming, the instructional module will reflect this. On the other hand, a pedantic approach to a subject and/or to programming of the subject will also unfortunately be faithfully reflected in the module. Thus, just as it is impossible to improve a textbook by changing the press used to print it, a computer-based instructional system will not generate quality in a curriculum module. Indeed, compared with other media, computer methods can amplify pedagogically poor techniques out of proportion.

The application of computer techniques to assist in teaching or learning can be categorized as follows.

1. *Computer Based Instruction* (CBI)—this connotes interactive special purpose programs that either serve as the sole instructional means for a course or at least present a module of material.
2. *Simulation*
   a. of experiments
      1. that allow "distributions" to be attributed to model parameters
      2. that are hazardous
      3. that are too time consuming
      4. whose equipment is too expensive
      5. whose principles are appropriate to the student's level of competence, but whose techniques are too complex
   b. for comparison of model results with measurements from the corresponding real equipment
3. *Data Manipulation* (can be interpreted as customarily conceived computation) for
   a. time compression/expansion—especially in the laboratory, as in data acquisition and reduction with immediately subsequent "trend" or "concept" display
   b. advanced analysis in which the computation is normally too complex and time consuming
   c. graphic presentation of concepts possibly deflections under dynamic loading, molecular structures, amplitude ratio and phase lead or lag, . . .
4. *Computer-Based Examination and Administrative Chores* to accompany self-paced instruction

SYSTEM DESIGN PHILOSOPHY

Design concepts that foster a synergistic relationship between a student and a computer-based educational system are based upon the following tenets.

1. The role of the computer in education is solely that of a tool which can be used by the average instructor in a manner that (a) is easy to learn, (b) is easy to control, and (c) supplements instructional capability to a degree of efficiency unattainable through traditional instructional methods.
2. Computer-based education, although relatively new, has progressed past the stage of a research tool. Pilot and experimental programs have been developed to the point where formal instruction has been conducted in courses such as physics[2] and chemistry.[3,4] Despite this, the full potential of these new techniques has yet to be realized. Future systems, that are yet to be designed, must evolve which will provide sufficient capacity, speed and flexibility. These systems must be able to accommodate new teaching methods, techniques, innovations and materials.

   Programming languages, terminal devices and communications should be so conceived as to not inhibit pedagogical techniques which have been successfully developed over the years. The system should incorporate new requirements which have been dictated through progressive changes in education and adjust without trauma or academic turbulence.
3. Initial computer-based instructional systems should be capable of moderate growth. Their role will be that of a catalyst to expedite training of the faculty as well as a vehicle for early development of useful curriculum matter. Usage by faculty will grow in parallel with evolving plans for future systems based upon extensive test and evaluation of current course matter.

The design of individual instructional modules to supplement laboratory instruction in the sciences and engineering will follow the general elements of the systems approach which has gained acceptance in curricular development.[5] This approach to curriculum design can generally be described as a method for analyzing the values, goals, or policies of human endeavor. The method as applied to computer-assisted instruction has been described in detail by Bunderson.[6]

Although there have been several different descriptions of the systems approach to the design of curricular materials, two major elements are always present: course analysis and profiling techniques. **Course analysis** consists of

1. ***a concise statement*** of the behavioral objectives

of the course expressed in terms of the subject matter that is to be learned.

2. ***the standard*** that each student must reach in the course.
3. ***the constraints*** under which the student is expected to perform (which may involve an evaluation of his entering skills).

The results of the course analysis lead to an implementation of the suggested design by incorporating a curriculum profile (**"profile techniques"**), which contains

1. ***function analysis,*** i.e., the use of analytical factors for measuring the parameters of a task function
2. ***task analysis,***[7] i.e., an analysis that identifies in depth various means or alternative courses of action available for achieving specific results stated in the function analysis
3. ***course synthesis,*** the iterative process for developing specific learning goals within specific modules of instructional material.

A general flow diagram which shows the relationship between the elements in the systems approach to curriculum design appears in Figure 1.

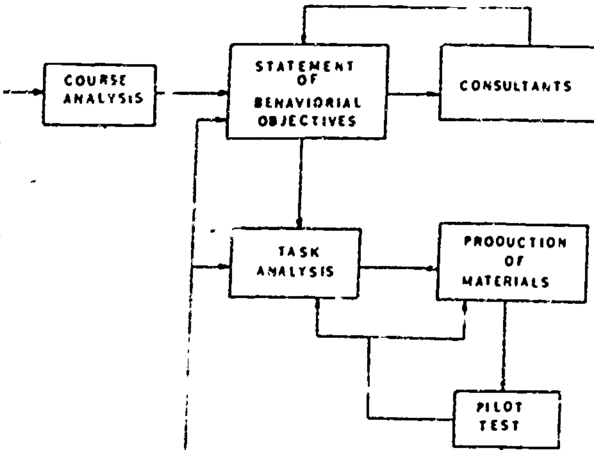

Figure 1—Systems approach to curriculum design

Goals and behavioral objectives

Some of the longer range goals defined should be to demonstrate quantitatively the increased effectiveness gained by computer-based techniques and further, to develop skill in the faculty for "naturally" incorporating information processing into course design. Another long range goal should be to effect real innovation in the notions of "laboratory courses" and finally, to instill in graduating students the appreciation that computers are for far more than "technical algorithm execution."

In more detail, some of the goals are to:

1. Plan, develop and produce computer-based course material for use in undergraduate science and engineering courses to supplement existing or newly proposed courses. Course matter developed will utilize a systems approach and consider entering behaviors, terminal objectives, test and evaluation schema, provisions for revision, and plans for validation in an institutional learner environment.
2. Produce documentation, reports, programs and descriptive literature on course matter developed to include design and instructional strategies, flow charts and common algorithms.
3. Test course matter developed on selected classes or groups for the purpose of evaluation, revision and validation. This is to determine individual learner characteristics through use of techniques such as item analysis, and latency response using interactive languages.
4. Promote and implement an in-depth faculty involvement and competency as to the nature, application and use of computer-based instructional languages, course matter and techniques.
5. Compile, produce and make provisions for mass distribution of such computer-based materials as are tested, validated and accepted for use by other colleges or institutions participating in similar programs.

In an academic environment the use of time-sharing computers for education is gradually being incorporated as a hard-core element, which in time will become so commonplace a resource for faculty and student use that it will serve as an "educational utility" on an interdisciplinary basis. To achieve a high degree of effectiveness of such systems, the faculty using computer-based teaching techniques as a supplement to laboratory type instruction must initially become involved. The pedagogical objectives of this whole approach are:

1. To correct a logistic imbalance: i.e., a condition marked by the lack of a qualified instructor and/

or the proper equipment and facilities to perform a specific teaching task (or project) being at a specific place at a specific time.

2. To provide more information per unit time so that, as time passes, the course will provide an increasingly in-depth knowledge.
3. To allow new ranges of material to be covered when one specifically considers things currently omitted from the curriculum because of student safety or curriculum facility costs.
4. To increase academic cost effectiveness, because it is certainly expected that adroit information processing will free the faculty from many mundane tasks.
5. To provide both parties with more personal time and flexibility, because it is anticipated that considerable amounts of time are to be made free for both student and faculty.
6. To make a computer-based system the key to the individualization of mass instruction by utilizing dial-up (utility) techniques.
7. To develop laboratory simulation so that it is no longer a constriction in the educational pipeline because of limited hardware and current laboratory logistics.

Evaluation criteria

In general, there are two distinct phases to the evaluation of instructional modules. The first of these coincides with the actual authoring and coding of the materials, and the second takes place after the program has advanced to its penultimate stage. These two types of evaluation can be referred to as "developmental testing" and "validation testing," respectively.

Developmental testing

This testing is informal and clinical in nature and involves both large and small segments of the final program. The specific objective of this phase of the development is to locate and correct inadequacies in the module. It is particularly desirable at this point of development to verify the suitability of the criteria which are provided at the various decision points in the program. It is also anticipated that the program's feedback to the students can be improved by the addition of a greater variety of responses. Finally, testing at this stage should help to uncover ambiguous or incomplete portions of the instructional materials.

Relatively few students (about 25) will be required at this stage of evaluation; however, since this phase is evolutionary, the exact number will depend on the nature and extent of the changes that are to be, and have been, made. Materials which are rewritten to improve clarity, for example, must be retested on a small scale to establish whether an improvement has in fact been made. A final form of this program, incorporating the revisions based on this preliminary testing, will be prepared for use by a larger group of students.

Validation testing

The formal evaluation of the programs will occur in a section (or with a part of a section) of a regularly scheduled class.

It is assumed that a selection of students can be obtained that is representative of the target population for which the materials are designed. One of the following two methods for obtaining experimental and control groups is suggested, depending upon circumstances existing at the time of the study (i.e., number of sections available, whether they are taught by the same instructor, the willingness of instructor to cooperate, section size, etc.).

The preferred method is to arbitrarily designate one course section *experimental* and one course section *control* with the same instructor teaching both sections. An assumption here is that the registration procedure results in a random placement of students in the sections. The alternative method of selecting students follows. The instructional programs are explained to the total student group early in the semester, and a listing of those students who are willing to participate is obtained. Two samples of approximately equal size are randomly selected from this list. One sample of students is then assigned to work with the computer-assisted instructional facilities and is designated as the experimental group.

The criteria used to evaluate the programs are as follows.

1. The extent to which students engage in and/or attain the behavioral objectives stated for the program. For tutorial and remedial programs pre- and post-tests are the instruments for measuring attainment and will help answer the question. Does the computer based supplement actually teach what it purports to teach? For experiment simulations, the successful completion of the program is *prima facie* evidence that the student has engaged in the desired behaviors.
2. Achievement as measured by the course final examination.

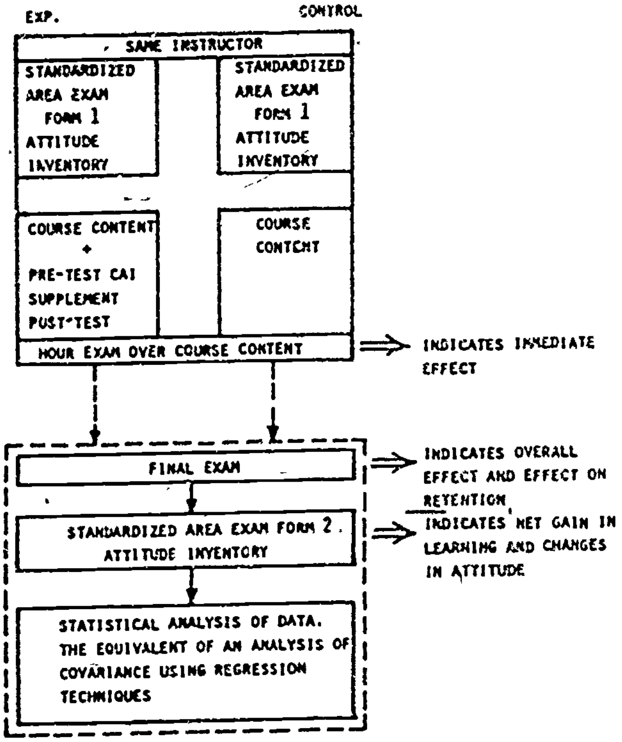

Figure 2—Test and evaluation schema for overall program

3. Net gain in achievement as determined by pre and post-testing with the appropriate standardized area examination.
4. Changes in student attitudes as measured by pre- and post-attitude inventories.

The statistical treatment used to evaluate the programs in light of the above criteria will be a multiple linear regression technique equivalent to analysis of covariance for criteria 2 and 3. The covariables used will include. (1) A placement exam score (if available); (2) the beginning course grade (for students in advanced courses); (3) sex; (4) SAT* scores, high school GPA**, and (5) other pertinent information available in the various courses. The key elements of the test and evaluation schema are shown schematically in Figure 2.

IMPLEMENTATION

Planning is one of the most important aspects of CBI and when done properly yields what we might call a "systems approach" to curriculum or course design. This means not only the setting up of a course of instruction by following a comprehensive, orderly set of steps, but also a plan for involving other faculty.

No two curriculum designers will agree as to what constitutes the essentials in outlining a course in its entirety before beginning. However, there are certain sequential or logical steps that can be defined precisely. These steps have been designated below as the course planning "mold" and are based upon actual in-house experience in planning, developing, testing and evaluation of course matter. Examples of this planning as shown in the entries in Tables I and II are authentic

* Scholastic Aptitude Test.
** Grade Point Average.

TABLE I—Curriculum Development Research Tasks

Task Title	Type Application	Research Investigator	Department
Machine Element Design	D, IG, MM, PrS, Res	Dr. J.J.A. Assistant Professor	Mech. Engr.
Aerospace Structural	D, IG, MM, PrS, Sim, Stat, Res	Dr. E.H.B. Assistant Professor	Aero. Engr.
Theoretical Chemistry	Sim, D, Rsim	Dr. F.A M. Professor Dr. R.W K. Faculty Associate	Chemistry
Biophysical Analysis	SIM, Rsim, Stat	Dr. J.L.F. Assistant Professor	Zoology

Application Code

D—Drill and Practice; G—Graphics; IG—Interactive Graphics; MM—Mathematical Modeling, Gaming; PrS—Problem Solving; OLME—On Line Monitoring of Experiments; Sim—Simulation; Rsim—Real Experiments Plus Simulation; Stat—Statistical Data Processing; Res—Research in Learning Processes.

TABLE II Curriculum Development Research Task Cost

Task Title	Duration (Mo.)	Total Dollar Value*	Personnel Cost	Computer Time Cost
Elements of Design	27	$72,440	$31,120	$41,320
Aerospace Structures	31	$111,720	$45,920	$65,800
Theoretical Chemistry	24	$53,150	$36,900	$16,250
Biophysical Analysis	19	$43,250	$23,600	$19,650

* Not including hardware cost

and have been derived by requesting each new associate investigator to fit the approach to beginning his work into a "mold." Descriptive material for each prospective participating faculty member is shown in the following example,* and is organized as follows.

1. Title
2. Introduction
3. Objectives
4. Project Description
5. Method of Evaluation
6. Impact on the Curriculum
7. Pedagogical Strategy
8. Current or Past Experience
9. Related Research
10. Plans for Information Interchange
11. Detailed Budget*
12. Time Phasing Diagram
13. Application Cross-Reference Chart

EXAMPLE OF A PROSPECTIVE ASSOCIATE INVESTIGATOR'S PROPOSAL:

INTERACTIVE DESIGN OF MACHINE ELEMENT SYSTEMS

Introduction

Engineering design is a structured information, creative process. The synthesis of physically feasible solutions generally follows many design decisions based on processed available information. The structure of design information has been defined in the literature.[5] Processing this design information in a scientific and logical method is important to the understanding of how one teaches engineering design, particularly the part that computer augmentation might play in the process. Essentially, the computer can relieve the engineering designer of those aspects of problem manipulation and repetitive computation that might otherwise distract him from the context of his problem. The fundamental principle here is to have the designer making decisions, not calculations.

Objectives

There are several objectives to being able to put a student in an interactive situation for the design of machine elements. One of the primary goals is to allow students to consider machine element systems instead of the traditional approach of the machine elements. The object of this is to show the interplay of the deflections and stresses due to imposed forces on machine element systems. Another objective is to allow distributions to be attributed to parameters of systems normally considered as discrete. Latest in the series of engineering texts are those that consider probabilistic approaches to design. Finally in the design process, by definition, a task performed at one instant in time does not give the observer of a designer any information about what the designer's next task might be. Hence, it is most important to construct an environment that will allow the student to "meander" through the myriad of possibilities of alterations of a nonfeasible solution of a design problem that might make it subsequently a feasible solution. Another objective of using an interactive system is so considerations not necessarily sequential in an algorithmic sense can be superposed for the student's consideration. That is, he can consider system reliability, system structural integrity, and system economics simultaneously and make design decisions based on any one of those fundamental considerations.

Project description

This project involves the integration into a conventional classroom of one or more reactive CRT displays. The addition of computer augmentation to the traditional teaching of engineering element systems design is proposed in order to satisfy the needs of the undergraduate student who would like to be able to synthesize and analyze more realistic element systems than is now pedagogically possible. The following specific desired functions in the computer-based system are necessary to make it an easily accessible extension to the student designer's functional capabilities:

1. Information storage and retrieval. The system must be able to accept, store, recall, and present those kinds of information relevant to the designer. For example, material properties, algorithms for analyzing physical elements, conversion factors, etc.
2. Information Interchange. The system must be able to interact with the designer conveniently so that he can convey information with a minimum of excess information during the operation of the system.[5]
3. Technical Analysis Capabilities. The system must be able to act on the information pre-

* It should be emphasized that the courses listed in Tables I and II represent only a portion of the curriculum matter which is being or needs to be developed.

* Sample forms for items 11, 12, and 13 can be obtained from the authors. The form for item 11 in particular gives the details necessary to arrive at a project's estimated dollar cost.

sented, analyze it, and present concise results to the designer.

4. Teaching and Guidance Capabilities The system must provide the student designer with information necessary to enable him to use the system and also to tutor him in the context of his problems.
5. Easy Availability—The system should be available to the student user and adaptable to his modifications.

In essence this project can be described as the design and implementation of a computer-based reactive element design system which would be as integral a part of a teaching environment as the blackboard, doors and windows. Further, in this project the amount of additional material in terms of reliability, value analysis, noise control and other modern engineering concepts that can be integrated into the standard curriculum can be conveyed more effectively and to a deeper degree.

Method of evaluation

The effectiveness of this method will be evaluated by presenting the students with more comprehensive design problems at the end of the semester. Several observations would be made. First, they would be able to take into account more readily the interaction between systems elements in a mechanical network. They should not require as many approximation with respect to fatigue life, method of lubricating bearings, etc.

Impact on the curriculum

The effect on the curriculum will be as follows. The Mechanical Engineering Department at The University of Texas has what is known as 'block" options. In this way, a student in his upper-class years may select some particular concentrated area of study. Part of the material that he now receives in one of his block courses 366N could be moved back to his senior design course 366K. The effects on the curriculum should be to free, for additional material, one-half semester of a three-hour course at the senior undergraduate level for those majoring in design

Pedagogical strategy

The strategy of the course at present is the solution of authentic design problems solicited from industry. However, all analysis techniques are currently confined to paper and pencil with computer algorithms where practical The new strategy will add the ability to analyze mechanical systems networks on an interactive screen and have an opportunity to manipulate many possible ideas (both changes in topology and changes in parameters) per unit time.

Current or past experience

The investigator has spent several years on the development of interactive graphic machine design systems both in industry and in academic institutions. Further, the investigator has been teaching the design of machine element systems since 1963 and prior to that practiced design of machine element systems since 1958.

Related research

Professor Frank Westervelt at the University of Michigan is currently conducting research in the area of interactive graphic design. His major emphasis is on the design of the executive systems behind interactive computer graphic systems. Dr. Milton Chace also at the University of Michigan uses some software generated by Dr. Westervelt's group. His concentration is on using Lagrange's method to describe dynamic systems and be able to manipulate the problem's hardware configurations on the screen. Professor Daniel Roos of the MIT Urban Systems Laboratory is now putting a graphic front end on his ICES system. Professor Gear at the University of Illinois has a system running on a 338/360-67 system and his primary interest there is to work with people who are manipulating electrical network topologies and doing network analysis. Professor Garrett at Purdue University is using graphic terminal access to his university's computer for performing a series of analyses on mechanical engineering components.

The unique aspect of the work that is envisioned here, as opposed to all above mentioned relative works, is primarily that it will be an instructional tool. That is, the computer is recognized as an analysis tool, a teacher, and an information storage and retrieval device.

With respect to each of the above, there are two connotations. With respect to analysis, the computer will perform analysis in its traditional sense of engineering computation and it will also analyze the topology of mechanical systems as drawn on the screen such that the excess information between the designer and the computer will be reduced. Concerning teaching, the computer will work with the student not only to teach him how to use the system, but also in another sense it will help him learn about his problem's context by techniques such as unit matching and unit conversion and checking topological continuity before allowing engineering computations. With respect to information storage and retrieval, traditional parameters such as material yield strengths and physical properties of fluids will be available.

Another concept in interactive design will be developed when the system can work with the student and help him optimize apparently continuous systems made up of objects such as bearings that only come in discrete quantities, for instance ⅛ inch increment bores, etc.

Plans for information interchange

Information interchange, of course, has two meanings: (1) how to get information from other schools to the University of Texas, and (2) how to disseminate the results of my research to other interested parties. It is the responsibility of the principal investigator to insure that information from professional society meetings, personal visits to other campuses, research reports, published articles, personal communication, and "editorial columns" in both regional and national newsletters of societies such as ASME, IEEE, SID, SCI, ACM, and others are disseminated to his research associates.

Further, it is the researcher's responsibility to generate research reports, published articles, take the responsibility for keeping his latest information in "news items," attend meetings, and write personal letters to other people in the field who are interested to help keep them abreast of his current research activity

EXPERIENCES TO DATE

Completed projects

During the academic year 1968-69 two pilot projects were conducted on the use of computer-based techniques in the instruction of undergraduate chemistry. Fifteen curriculum modules were written for the General Chemistry project and eight for Organic Chemistry. In each instance the modules covered subjects typical of the material found in the first semester of each course. Each module was "debugged" and polished by extensive use of student volunteers prior to use in the pilot studies. In each study, the modules were used to supplement one section of the respective courses under controlled conditions. Results from this two-semester study on computer-based applications in organic chemistry indicate a high degree of effectiveness. Not only was the study effective in terms of student score performance, but also in terms of outstandingly favorable attitudes towards computer-based instruction by students and professors.

Concurrently, faculty members of the College of Engineering have also conducted various courses using computer-based techniques. Dr. C. H. Roth of the Electrical Engineering Department has developed a computer-assisted instructional system that simulates a physical system and provides computer-generated dynamic graphic displays of the system variables.[9] An SDS 930 computer with a display scope is used for this project. The principal means of presenting material to the students is via means of visual displays on the computer output scope. A modified tape recorder provides audio messages to the student while he watches the scope displays. A flexible instructional logic enables the presentation of visual and audio material to the student and allows him to perform simulated experiments, to answer questions (based on the outcome of these experiments) and provides for branching and help sequences as required. Instructional programming is done in FORTRAN to facilitate an interchange of programs with other schools.

Dr. H. F. Rase et al.,[10] of the Chemical Engineering Department have developed a visual interactive display for teaching process design using simulation techniques to calculate rates of reaction, temperature profiles and material balance in fixed bed catalytic reactors.

Other computer-based instructional programs developed include similar modules in petroleum engineering and mechanical engineering. In each instance, the curriculum modules are used to supplement one or more sections of formal courses. In several instances it is possible to measure the course effectiveness against a "control" group. Course modules generally contain simulated experiments, analysis techniques using computer graphics and some tutorial material.

The general objectives for all of the aforementioned studies are as follows:

1. To give the students an opportunity to have simulated laboratory experiences which would otherwise be pedagogically impossible.
2. To provide the students with supplemental material in areas which experience has shown to be difficult for many students.
3. To provide a setting in which the student is allowed to do a job that professionals do; i.e., collect, manipulate and interpret data.
4. To give the student the feeling that a real, con-

cerned personality has been "captured" in the computer to assist him.

5. To individualize the student computer interactions as much as possible by allowing the student to pace himself.
6. To give the student a one-to-one situation in which he can receive study aid.

Present state of computer-based learning systems

Curriculum development in engineering and the sciences is being accomplished within the University of Texas through the Computation Center CDC-6600 system using conversational FORTRAN within the RESPOND time-sharing system. Also, small satellite pre- post-processors such as a NOVA, a SIGMA 5 and an SDS-930 are linked to the CDC 6600. Of special significance is the Southwest Regional Computer Network (SRCN) which is now in the early stages of use and is built around the CDC-6600. Some eight intra state colleges and universities are linked. Workshop and user orientation sessions are still under way concurrent with curriculum development. The integration of course matter for this network will be accomplished during the next two to three years. A discussion of the factors involved in curriculum software development and some evaluation aspects follows.

Cost factors and management considerations

When developing an accounting system for examining the cost of generating software for teaching, one readily realizes that there is the traditional coding and the subsequent assembly and listing. However, because academic institutions frequently have this class of endeavor funded from agency sources, a next step is very frequently hardware installation at the terminals or the central processor have not been "on board" prior to the initiation of the research. Once the hardware is available, however, on-line debugging can take place and the first course iteration can begin. The next step is the first course revision in which the material is rewritten, possibly restructured, to take advantage of experiences on the first pass. Then, the second course iteration is performed and finally the second course revision.

The estimates for coding, assembly, listing, and debug time, etc., are a function of

1. the computer operating system and its constraints,
2. the coding proficiency of the professionals involved,
3. the way in which the computer is supposed to manifest itself, that is:
   a. as a simulation device in parallel with the real experiment,
   b. as purely a simulation device,
   c. as a base for computer-augmented design,
   d. for data acquisition,
   e. for computer-based quizzes,
   f. for computer-based tutorial and drill,
   g. or finally, for computation.
4. the degree of reaction required, that is in the physiological sense, how the computer must interact for the user's latent response.
5. the extent of the data base required and the data structure required to allow one to manipulate that data base.

The primary considerations are organization and control. In this work the organization consists of the following. At each college there is a project coordinator who is the line supervisor for the secretarial services, programming services, and technical implementation services, and who acts as the coordinator for consultants.

At the University level there exists a review panel, composed of members of the representative colleges and several people from other areas such as educational psychology and computing, which evaluates the works that have been conducted in any six-month period and also evaluates the request for continuation of funds to continue a project to its duration. The actual fiscal control of each project is with the project coordinator of that particular college. Also, the purchase of equipment is coordinated at the college level.

The control as expressed above is basically a two-step control, a bi-annual project review, plus a budgetary analysis, is accomplished by an impartial review panel. Their function is to act as a check on the context of the material presented and to recommend continuance of particular research tasks. As a further step, this research is coordinated in all colleges by the Research Center for Curriculum Development in Sciences and Mathematics.

SUMMARY

Dissemination of information

Dissemination of information is planned through (1) documentation of publications in the form of articles, reports or letters, (2) symposia to be held which cover procedures and fundamentals for developing curriculum in CBI and (3) furnishing of completed packages of course matter on computer tapes, cards or disks to other colleges or institutions desiring, and able to use, this material. Wide publicity will be given completed course matter through such agencies as ERIC, ENTELEK and EDUCOM. The provision for continuing periodic inputs to the above agencies will provide for current availability of curriculum materials.

Future outlook

The future outlook for time-sharing in computer-based educational systems is extremely bright with respect to hardware development. The advent of the marketing of newer mini-computer models selling for five to ten thousand dollars—some complete with a limited amount of software—is already changing the laboratory scene. The configuration of direct-connect terminals, with the inherent advantage of installation within one building, further enhances the use of this type of system by eliminating the high expense of data lines and telephones.

Software in the form of a powerful CBI language for the sciences and engineering designed specifically for minicomputers is perhaps one of the most important needs. Rapid progress has been made in developing a low cost terminal using plasma display or photochromic technology; however, the promise of a low cost terminal has yet to be realized.

A small college, high school or other institution may be able to afford a small time-sharing computer system with ten terminals that could meet its academic needs for less than $36,000; however, still lacking is the vast amount of adequate curriculum matter. Educators using CBI are in the same position as a librarian who has a beautiful building containing a vast array of shelves but few books to meet academic needs of students or faculty. The task of curriculum development parallels the above situation and must be undertaken in much the same manner as any other permanent educational resource.

Educational benefits

Benefits that result from implementing this type plan are a function of the synergistic interplay of (1) personnel with expertise in the application of computer-based techniques, (2) computer hardware including interactive terminal capability, (3) faculty-developed curriculum materials; and (4) the common information base into which the entire research program can be embedded.

The program can provide students with a learning resource that serves many purposes. That is, the computer can be the base of a utility from which the user can readily extract only that which he needs, be it computation, data acquisition, laboratory simulation, remedial review, or examination administration. At all times the computer can simultaneously serve as an educator's data collection device to monitor student interaction. This modularized dial-up capability can give the students an extremely flexible access to many time-effective interfaces to knowledge.

Administrative benefits

When this type project has been completed, all users may have access to the results. This unified approach can yield modules of information on cost accounting which can be used as a yardstick by the University.

Further, this type project insures that data-yielding performance is of a consistently high quality, and that regardless of the subject matter on any research task the depth of pedagogical quality is relatively uniform.

The subject matter developed can serve as the basis for conducting experiments in teaching and continuing curricular reform. Indeed, the association of faculty in diverse disciplines can serve as a catalyst for curricular innovations in the course of preparing materials for computer-based teaching techniques.

The instructional efforts described here can serve as the basis for displaying the unity of science and engineering to the undergraduate student in an indirect way. For example, if a student is taking a set of science courses in a particular sequence because it is assumed each course contributes to an understanding of the next one, it is possible to use programs developed in one course for review of remedial work in the next higher course. Thus, an instructor in biology can assume a certain level of competence in chemistry without having to review the important points in the latter area. Should some students be deficient in those aspects of chemistry that are important to the biology course, the instructor can assign the suitable material that had been developed for practice and drill *for the preceding chemistry course*. With a little imagination, the instructional system can make a significant impact on the student by giving him a unified view of science or engineering. It is possible to develop both a vertical and horizontal structure for common courses which can be used on an interdisciplinary basis for integration in the basic core curriculum in the various departments where computer-based techniques are used. The revision problem of inserting new and deleting old material in such a system is considerably simplified for all concerned.

There is a vast, largely unexplored area of applications. As time-sharing methods become more widespread, terminal hardware becomes less complex, and teleprocessing techniques are improved, the potential usefulness of computers in the educational process will increase. With the technology and hardware already in existence, it is possible to build a computer network linking industries and universities. Such a network would (1) allow scientists and engineers in industry to explore advanced curriculum materials, (2) allow those who have become technically obsolete to have access to current, specifically prepared curriculum materials, training aids and diagnostic materials, (3) allow local curriculum development as well as the ability to utilize curriculum materials developed at the university, (4) allow engineers to continue their education, (5) provide administrators with an efficient and time-saving method of scheduling employees and handling other data processing chores such as inventories, attendance records, etc., and (6) provide industrial personnel with easily obtainable and current student records to aid in giving the student pertinent and helpful counseling and guidance.

Although complaints have been voiced that computer-based techniques involve the dehumanization of teaching, we argue to the contrary—the judicious use of these methods will individualize instruction for the student, help provide the student with pertinent guidance based upon current diagnostic materials and other data, and allow instructors to be teachers.

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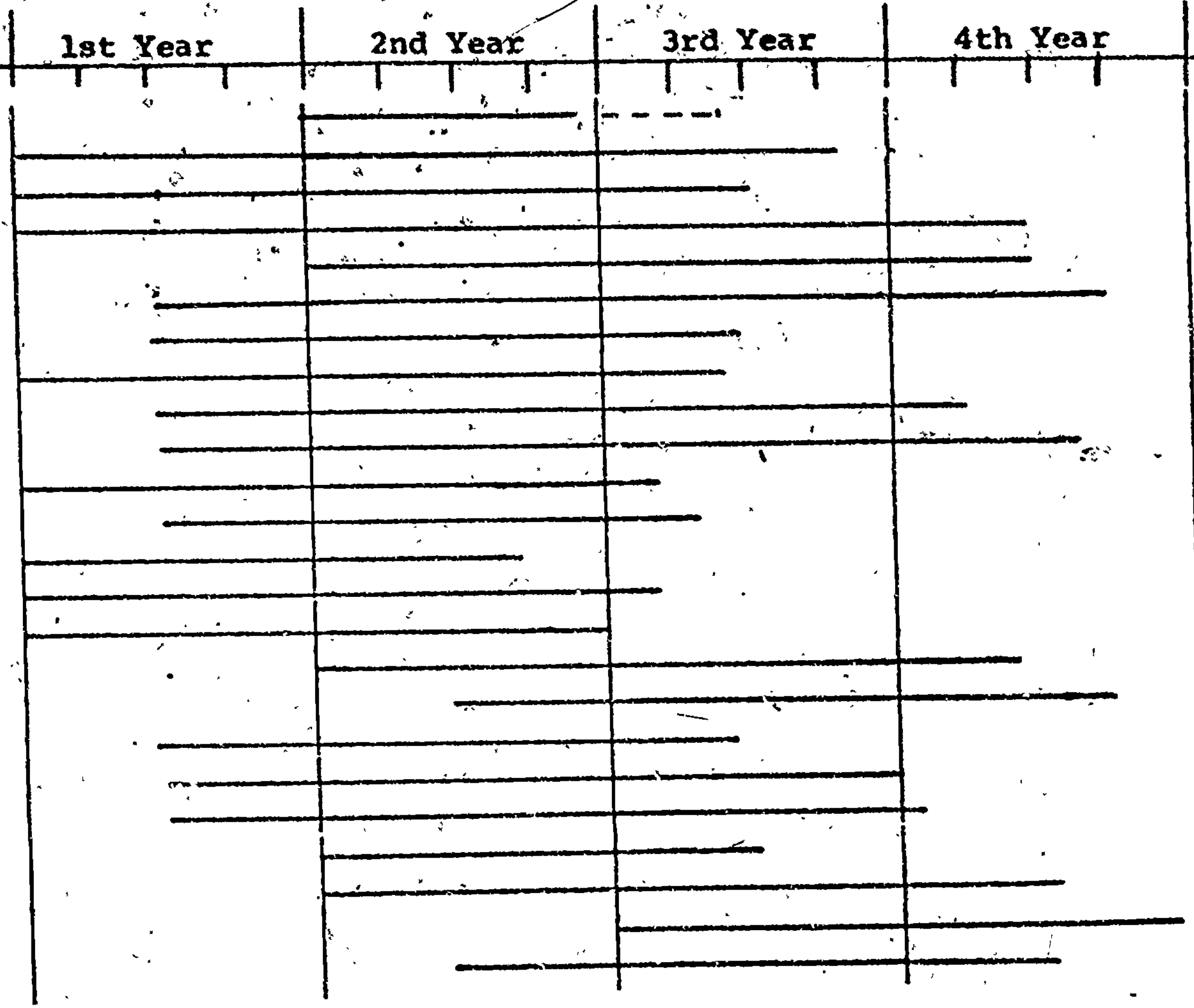
TIME PHASING OF ALL PROJECTS



Project	Duration in Months
Self-Paced Instruction	17
Statistics	32
Hybrid Computing	30
Nuclear Engineering	41
Thermodynamics	30
Petroleum Engineering	39
Power Systems	24
Design of Machine Elements	29
Aerospace Structures	33
Aerospace Analysis Problems	38
On-Line Process Simulation	26
Network Analysis	22
Civil Engineering	20
General Chemistry	26
Organic Chemistry	24
Physical Chemistry	29
Theoretical Chemistry	27
Biophysical Analysis	23
Biometrics	30
Physics	31
Population Studies	18
Principles of Economics	30
Experimental Psychology	23
Econometrics	24

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