Apr 1st, 8:00 AM

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INTRODUCTION OF COMPUTER-AIDED INSTRUCTION
INTO AN AEROSPACE ENGINEERING CURRICULUM

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Summary

The computer-aided education program at
the U. S. Naval Academy has developed over
a two-year period a nucleus of well train-
ed and experienced faculty and technical
staff members. The overall approach being
used to introduce the use of computer-
aided instruction into the academic pro-
gram is described. Details of the parti-
cipation of the Aerospace Engineering
faculty in this program, and the work done
to date in courses which support the Aero-
space Engineering curriculum, are present-
ed.

Introduction

Within the past few years, the concept
of time-sharing with remote on-line ter-
minals and the development of relatively
simple programming languages have provided
an opportunity for the widespread use of
the computer in the classroom and in re-
lated educational activities. New philos-
ophies, concepts, and objectives have been
stated concerning the role of the computer
in education.

Realizing that the use of the computer
as an aid to education is in its infancy
and that the potentials of computer-aided
education appear limitless, the U. S.
Naval Academy Computing Center embarked on
a unique approach to the introduction of
computer-aided instruction in its academic
program.

The purpose of this paper is to discuss
the three phases of the overall approach
(informative, operational, and planning)
as related to the Aerospace Engineering
curriculum.

Time-Sharing Concept in Education

The major development which is revolu-
tionizing the use of the computer in edu-
cation, as well as in the overall data
processing field, is time-sharing.[1] "Time-
sharing is a mass distribution technique
developed for and applied to data process-
ing. Its primary, underlying function has
been to make more computer power available
to more users."[2] It permits a number of
persons to use the same computer facility
at the same time through the use of remote
terminals.

What does this mean to the instructor

in the classroom? He can let a classroom
of students use a computer at another loca-
tion by means of a telephone line; each
student communicating with the computer;
each student getting service from the cen-
tral computer system as if he were the only
person using it. Ideally, the teacher
would have a classroom with one remote ter-
minal for each student. If such a class-
room were available, the instructor would
prepare computer programs which the com-
puter needed in order to aid him in teach-
ing the course, file these programs in the
computer storage unit, and tell the stu-
dents which programs to call up and when.

Then it would be possible for the com-
puter, through the stored programs, to make
assignments, drill the students on assigned
material, quiz the student and store his
grades, pose problems and disscuss them
with him, and do many of the more routine
or straightforward things an instructor
would do. The most important of the com-
puter's advantages is its ability to deal
with each student in the class as an indi-
vidual and permit each student to progress
at his own best speed. When the suitable
portions of a complete course are pro-
grammed and in storage, a student can call
up programs as fast as he can get through
them. The slower student will take more
time with each program and may have to con-
sult his textbook or his instructor more
often than the faster student. The impor-
tant thing is that each student will have
met the same educational and behavioral
objectives satisfactorily if the programs
are designed properly.

In addition to permitting students to
maintain their own paces, the computer can
illustrate with numerical examples the
effects of varying single parameters in
complex problems. For example, in a flight
performance problem, the computer can ask
the student to select a range of altitudes,
then tabulate or plot the thrust required
and thrust available curves for a given
aircraft at the selected altitudes. Having
seen the effect of altitude on the perform-
ance of the aircraft, the student can then
select gross weight, wing area, aspect
ratio, or equivalent parasite area as the
parameter and see the effect of the select-
ed parameter on the performance.

Another advantage of the computer is
that it can be programmed to simulate ex-
periments. For example, a program could be
set up to produce lift and drag force data

if the student provides certain input about the test model and the wind tunnel test conditions. Of course, the computer is very useful to each student for performing the tediously repetitive calculations associated with the reduction of acutal test data.

These are some of the obvious uses of the computer in computer-aided instruction. Others are a straight tutorial use, review work, demonstration purposes, and homework. More effective uses are certain to be found as work in this field progresses very rapidly. We have discovered, however, that it takes a tremendous amount of time and talent to put the computer to work in the relatively simple ways mentioned here.

Overall Approach

Let us now look at the overall approach which we are using to introduce the computer as an aid to the instructor in the academic program. The approach is divided into three general categories: (1) informative, (2) developmental/operational, and (3) planning.

Informative Phase

The informative phase is of prime importance since it is necessary to have members of the faculty who are well versed in computer-aided education. To date, the informative phase has consisted of three courses designed to orient a nucleus of the faculty to new educational technology systems.

The first course was a Faculty Orientation and Feasibility Study[3] which was an eight-week course during the summer of 1966. It was designed to investigate the feasibility of using time-sharing remote terminals in education and to familiarize faculty members with the actual use of remote terminals, time-sharing techniques, and computer-aided education systems. The program consisted of lectures and demonstrations in the morning, and a workshop in the afternoon during which the participants used the remote terminals, worked with various systems, and carried out their individual projects in preparing instructional material which they used later in the "spot testing" portion of the operational phase. Fifteen faculty members representing the various academic departments at the Naval Academy participated. The response of the faculty to the potential use of remote terminals in the classroom was extremely enthusiastic. Teletype remote terminals were placed in several academic departments so that spot-testing might take place in the academic year 1966-1967.

Recognizing the importance of the continuing development of the faculty, the Computing Center at the Naval Academy organized a second faculty orientation course in Educational Technology.[4] It was de-

signed to prepare faculty members for the task of constructing courses using emerging educational methods and techniques.

The participants were exposed to the problems involved in writing course objectives in behavioral terms and were given experience in writing and programming objectives for courses they taught. They discussed the following items concerning the different modes of educational technology and their application to instructional material:

a. The preparation of course and behavioral objectives.

b. Theories of learning and of individualized instruction.

c. Presentation of course material (programmed instruction, computer-aided instruction, films, slides, text, audio, etc.).

d. Development of criteria for the selection of the best media of presentation for attaining particular behavioral objectives.

e. Use of computers in the educational environment.

f. Role of the instructor in the educational system that uses the computer.

Twenty faculty members attended this course for ten weeks (100 hours) during the latter part of the Fall Semester, 1966. These faculty members formed the hard core group that began developing computer-aided courses and encouraged additional faculty members to participate.

In the Spring Semester of 1967, approximately twenty faculty members and as many technical staff members participated in a Media Preparation course, a unique systems approach to the preparation of course material. Towards the end of the course, members, systems analysts, instructional programmers, and operators were organized into several teams which prepared course material to be used in the computer-aided instructional system.

Developmental/Operational Phase

The developmental portion consists of the current research effort in which the main objective is to test and evaluate the course material and method of instruction. Specific objectives are:

a. To select specific courses for development.

b. To prepare and define the course objectives in behavioral terms.

c. To outline course strategies.

d. To prepare and program course material.

e. To validate course material.

It is in this portion that the course

materials are tried and revised until they are ready for use in the classroom. Continued monitoring, evaluation, and revision of the developed course will provide experience which will help in the design of future course materials.

Actually, the developmental portion is divided into three distinct parts which are being treated individually, although they are closely related and built one upon the other. The three parts are:

a. Spot Testing the use of the General Electric and CEIR time-sharing computer systems located in Washington, D.C. Nine remote teletype terminals (standard Model 35 teletype machines), Figure 1, were located in various classrooms during the academic year 1966-1967. The objectives were to provide the opportunity for faculty members to learn the BASIC and FORTRAN computer languages and how to use the GE and CEIR time-sharing systems, and to develop instructional and computational programs for demonstration or individual student use in the classroom and in laboratory work.

b. Problem Solving with the GE and CEIR systems. Ten teletype terminals are located in an experimental classroom especially designed for this purpose, Figure 2. Students use the classroom teletype terminals for parametric studies, data reduction, laboratory simulations, quizzes, and drill and review exercises on instructional material. At present, instructors in two courses, Aero Performance and Electrical Science, are using the remote terminal classroom to aid them in instructing several student sections.

c. Computer-Assisted Instruction on the IBM 1500 Instructional System. This system is designed solely to present course material and presently services twelve student carrels in a second experimental classroom. Each carrel, as shown in Figure 3, is provided with: (1) a cathode ray tube (CRT) to display programmed material and responses which the student enters by means of a typewriter or a light pen pointer; (2) a projector for displaying slides and film; (3) the typewriter, which prints on paper as well as the CRT; and (4) a closed circuit television receiver. At present, material is being prepared and tested for presentation on this system in three courses: Thermodynamics, Electrical Science, and Physics.

Actually, the operational portion of this phase is a broadening of the base so that more courses can be developed and programmed, and more students will take their courses or portions of their courses using computer-aided instruction.

Planning Phase

Many aspects such as faculty and technical staff support, course and curriculum development, test and evaluation, and hardware and facilities have entered in the planning and must be considered continuously. Most significant in the future plans for course development is the multimedia concept, in which a scientific systems approach is applied to the educational environment. The newest teaching techniques and educational technology will help to structure a course. Each segment will be examined and evaluated in terms of its particular function and its relation to the complete system which may comprise any or all of the following media: programmed instruction, audio presentations, educational television, computer-assisted instructions, film and slide presentations, standard text, and lecture and tutorial sessions. A model for this future concept is presented in Figure 4.

Spot Testing

Time-sharing remote terminals were introduced into basic courses in the Aerospace Engineering curriculum during the academic year 1966-1967.

Fall Semester

Nine remote teletype terminals were located in classrooms throughout the Academy with one located in the Engineering Department. Emphasis was on the familiarization of additional faculty members with time-sharing and the use of the remote terminal. Discussions, seminars, and demonstrations were held for interested faculty members with emphasis placed on programming in BASIC. By the end of the semester, approximately twelve faculty members in the Engineering Department could use the time-sharing systems.

"Spot testing" of sample programs was carried out in two courses (Fluid Mechanics II, Vibration and Flutter of Flight Vehicles) by two faculty participants in the Summer Faculty Orientation Course. Because only one remote terminal was available, the sample programs were mainly used for demonstrating selected material to the classes. The typed copy was projected on a screen for the benefit of the entire class through the use of an overhead opaque projector. A student operated the remote terminal during the demonstration while the instructor explained the procedures. Individual students in these classes were also able to use the remote terminal and try the sample programs.

Spring Semester

Numerous programs were developed by faculty members and students as "spot testing" continued during the Spring Semester. Two remote terminals were made available because of the increased usage. The

computer programs developed come under several general headings: quiz, test data reduction, tutorial, classroom demonstration, design calculations, solutions to case problems, homework, laboratory simulation, and student and faculty research projects.

Quiz A multiple choice quiz program was developed in basic aerodynamics. The format of this particular quiz gives the student the option of repeating the question or going on to the next question if he gives a wrong answer. Questions using numerical values use a random number generator in the program in order to change the numerical values if a student repeats the question. Therefore, the student cannot find the correct answer by a process of elimination. The computer totals the right and wrong answers and does the scoring for the instructor. Questions can be changed quite easily and variations introduced as desired. Only a small number of students had the opportunity to work the quiz. All of their reactions were very favorable.

Laboratory Simulation An interesting routine was used in a first attempt to simulate a wind tunnel laboratory experiment which measures basic aerodynamic forces. The student has three choices of things to do: (1) answer a question, (2) conduct a wind-tunnel test, or (3) perform calculations on test data. The student is first presented several questions. In order to get sufficient information to answer any of the questions, he must run one of several simulated wind-tunnel tests programmed on the computer. Before running the test, the student is free to select the wing area of the model being tested and the test conditions, wind velocity, and angle of attack. Any one of these parameters may be varied over a range of specified values for a given test. After receiving the simulated test data, the student can select one of several possible calculations to reduce the raw test data to a usable engineering form. Having sufficient data, he can then proceed to answer one or several of the original questions. Several students used the program and found it to be a good preparation for using the actual wind tunnel facility. It familiarized them with the quantities measured, the typical range of numerical values, and the important test parameters which they could vary.

Design Special mention should be made of the use of the remote terminals in the Aerospace Engineering Design course. The programs developed were mainly computational programs with which students obtained preliminary numerical results quite rapidly for numerous design conditions. This permitted the students to investigate and evaluate several alternative designs at the same time and to pursue more numerous creative ideas. The so-called "guided" or "controlled" approach, generally used

in a design course, was greatly relaxed because of the reduced time required to carry out the usual laborious preliminary design calculations. The students were able to make more intelligent design decisions because the rapid computer calculations gave them more numbers on which to base their decisions. Typical design programs developed provided the following information:

a. Lift to drag ratio of a lifting body moving at hypersonic speeds.

b. Airfoil geometry and chordwise weight distribution of helicopter rotor blade.

c. Wall thickness of a booster consisting of a cylindrical section, conical skirt, and flat bulkhead.

d. Drag of an aircraft flying at subsonic and supersonic speed.

e. Take-off performance of a seaplane.

f. Longitudinal static stability characteristics of an aircraft in subsonic flight.

g. Spanwise lift distribution for an airplane wing.

h. Landing and take-off distance of an aircraft.

i. Stresses in a missile standing on a launching pad.

j. Thrust of a ramjet engine.

k. Range and endurance of an aircraft.

Case Problem Computer calculations for obtaining solutions in case problem studies were extremely useful. In most cases the student provided the necessary input data and used computer programs to carry out the calculations. The student, sitting at a remote terminal, was able to change any of the input data immediately by typing in the new values. Thus, the student could readily observe and understand more clearly the effect of various operating parameters on the final results, such as engine or aircraft performance. One of the most useful programs in the Aero Case Problem calculated preliminary design data for an aircraft. The program was also set up to reduce wind tunnel lift and drag data.

Another case problem study required the student to be familiar with reciprocating engine power plants. A special program gave him a brief background in internal combustion engine performance. Then he could obtain performance curves in the laboratory and use them to compare reciprocating engine power plants with other types in order to select the optimum power plant for a case problem. The program permits the student to select a number of variations to illustrate the effect of selected losses in the actual engine. The student may have the results printed out, plotted in curve form, or both. The

program will recycle so that the student may: (1) change scales of the plot, (2) vary the air/fuel ratio, (3) change engine design parameters, or (4) vary the type and number of losses to be considered. The use of this program gave the student a means for examining the relationship between the pertinent input data and performance results and, if so inclined, for delving into the study to a much greater degree than heretofore possible.

Tutorial Very little was done with tutorial programs because of the slow printing speed of the present teletypewriter.

A tutorial approach to the determination of the centroid of composite areas was developed. Two separate programs were required because of the size limitation (6000 characters) of a program. The first program is a pre-test to find out if the student has a minimum prerequisite knowledge. Questions concerning the centroids of a circle, triangle, and rectangle are asked. If the student gives a wrong answer, diagnostic statements are presented to the student. The second program asks the student to calculate the centroid of composite areas. The student has a choice of subareas which he may investigate to solve the problem. Inputs are provided through the student responses to questions. The student answers are printed with the correct answers. The student may then rework the problem or continue on. The student reaction to this approach was very favorable. Each student works at his own pace and provides his own input. The student experiences a great sense of accomplishment when he gets the correct answer on his own.

A similar approach was used in computing the trajectory of a ballistic missile after the thrusting phase has been completed. The first program lists the equations of motion and the assumptions, plots a schematic representation of the problem, and asks questions regarding the assumptions and equations of motion. If any answer is wrong, the student is immediately given the correct answer. The second program computes the trajectory after the student provides certain data such as burnout velocity, altitude at burnout, elevation, drag coefficient, or weight.

Demonstration Numerous programs were developed by faculty members for demonstration to the class. Many of these were very effective in illustrating certain engineering concepts, techniques, methods of solution, and effects due to a variation of parameters which were only briefly discussed in course work previous to the use of the remote terminal.

One excellent example is the numerical integration of the Falkner-Skan equation for the viscous boundary layer flow over a surface. This program was used as a demonstration program and as a homework program for individual use by a student. For the first time, the instructor was able to demonstrate in the classroom the numerical solution of the Falkner-Skan equation for several values of the pressure gradient parameter. He could show the effect of the chosen initial condition on the final results, discuss and demonstrate iteration schemes, show the effect of step size on the accuracy of the numerical results, and show the existence of numerical instabilities. Student use of the program permitted the assignment of homework problems since the calculation time was greatly reduced in comparison with calculations performed with electronic hand calculators.

Other Uses Mention should be made of the many programs developed in student and faculty research projects, checking student homework, and data reduction.

Spot-testing was also conducted in the important related areas of Electrical Engineering, Chemistry, and Physics[5,6,7].

Problem Solving

The purpose of the problem solving phase of the overall program is to evaluate the effectiveness of the GE and CEIR time-sharing remote terminal systems in courses which lend themselves to problem solving; i.e., courses which make use of a large number of example numerical problems can use parametric studies to illustrate basic principles, and have relatively short homework reading assignments. Two courses, Aero (Flight) Performance and Electrical Engineering, are presently being developed and programmed. Segments of each course were tested with several groups of students during the Fall Semester, 1967. Additional material is being developed, programmed, and tested during the present Spring Semester, 1968. These courses make use of the experimental classroom illustrated in Figure 2.

Aero (Flight) Performance

The development of the Aero Performance course was started in June 1967. A considerable amount of time was spent in determining the course objectives, followed by stating the behavioral objectives of the individual lessons. In order to do this, one must examine the course in great detail. The net result was a revision of the course content. It can also be stated that if the instructors return to the classroom to teach the course, using the conventional lecture system, they will do a much better job in presenting the material because of their microscopic examination of the course. Several interesting programs have been developed for very specific reasons to aid the instructor in the classroom: pre-lecture quiz/study routine, grading routine, review of course material, wind tunnel data reduction, and graphical demon-

stration of the effect of changing parameters.

Pre-lecture Quiz/Study Routine The objectives of this program are:

a. Point out key definitions or points from previous assignments or areas of study.
b. Quickly bring all students to at least a minimum acceptable level of knowledge.
c. Correct erroneous student information.

The basic routine is matching of "words" to a set of "definitions." Definitions are paragraphs, sentences or equations that can be identified, described, or completed by a fifteen-character word and are provided to the student in a printed list of eight or twelve at a time. Words are alpha-numeric variables in the XBASIC language and may be numbers, equations, or several short words stored as data within the program.

The program has four basic parts:

I. Selection of definitions thought to be known by the student.

II. Presentation and brief study of correct answers to definitions unknown by the student.

III. Quiz on Part I definitions and presentation of correct answers to correct wrong ideas of the student.

IV. Final quiz on all definitions.

A grading routine takes into consideration student performance in each part. Credit is deducted for incorrect or unknown answers with a factor of one in Part I, a factor of two in Part III, and a factor of three in Part IV, in an attempt to force the student to admit his deficiencies early in the program.

The student reads the full list of definitions, selecting those he thinks he can identify. The computer grades his response, and then presents correct definition numbers for unidentified words. When the student has studied and is ready to continue, the computer presents, in groups of four and at random, words considered known from Part I. The student enters a definition number for each word. The computer grades his answers, gives the correct definition numbers, and then four more words. The student is given the number of questions he identified correctly and then he takes the final quiz. Again, random words are presented in groups of four and the student enters definition numbers. No answers are given, but at the end of the program the computer tells him how many he got right and what his grade was for the entire routine. Then it tells him to call up a grading program for his

class section, and he enters his grade and reads his average to date. The important feature of the quiz program is that the student refers to the definition list four to five times during the routine and therefore is drilled with definition names, equations, etc.

This program was used with fourteen different word lists, and the student reaction was good. It is easy to prepare new programs (about ten minutes), once the instructor has come up with a dozen significant items for the new quiz. On an average, it takes twenty minutes for a class of ten students to run the program. If the program could be trimmed to seven or eight minutes, it would be even more effective.

Grading Routine The grading routine program provides a grade bookkeeping system for the instructor and student. When the student enters his name and latest test grade, the computer responds with the number of tests he has taken, his new average, and the most recent class average excluding his new grade. When the code word "GRADES" is entered, the computer responds with a list of students, their current average, and number of tests taken. The program also gives class average.

Student response was good, with the relative position of each student with respect to the class average providing an incentive to do better.

Drill/Review A program which presents multiple-choice questions was developed to review course material and provide the opportunity for basic drill for use outside the class period.

At present, the program has three topic areas with six or seven questions in each. The questions each have three possible answers identified by a changing tag number. Question by question the student inputs the tag number that identified his answer to the previous question and the number that identifies his choice for the next topic. Each time a topic is selected, the question provided from that topic is in sequential order until all six or seven questions have been used, then the order starts again for that topic. The number of questions taken and the number of questions answered correctly are given at the end of the program.

It is easy to change the topics and questions in the basic program. The program is being expanded and improved, and can be used as a pretest to measure the general knowledge of the student at the beginning of the course.

Student response was very favorable, particularly in the group of students with average and below average grades. This type of program will play an important role when more remote terminals are provided throughout the Academy, especially in

dormitory and evening study areas.

Parametric Study One example of a problem-solving type of computer program is that developed to show the student the effect of various parameters on thrust required for an aircraft in flight. Two curves are plotted and a graphical comparison of the curves is made.

After passing a four-question barrier quiz on the drag equation, the student selects the secondary variable of weight, altitude, or configuration (flat plate area) to change in order to see its influence on drag. A simultaneous double plot of drag versus velocity, using high and low values of the secondary variable, is presented by the computer. The graph is based on inputs of primary constants (wing area, aircraft efficiency, and aspect ratio), lower limit values, and predetermined increments of the secondary variables. After all three secondary variables are investigated, the constants can be changed and the investigation continued.

Data Reduction Approximately ten computer programs have been written to reduce the test data for laboratory exercises and tests conducted in the wind tunnel. The programs reduce aerodynamic force data or pressure data for a specific test model, but they are not just a straightforward computerized reduction of test data. The student has to respond to statements or questions presented by the computer before the actual computations are performed and results tabulated or plotted.

One of the most sophisticated programs was developed for determining the performance of an aircraft based on model test data. The objectives of the program are:

a. Given lift and drag data from the wind tunnel balance system, tabulate and plot lift and drag coefficients for an aircraft model.

b. Given maximum lift coefficient, weight, and altitude of the full-scale aircraft, tabulate values for the aircraft drag polar (C_L versus C_D) based on model data.

c. Based on values of the aircraft drag polar, tabulate velocity, thrust required, and power required.

Atmospheric pressure, average temperature, four lift and four drag tare readings, and lift and drag data for all runs (different angles of attack) are entered as data into the program. Density, dynamic pressure, velocity, and various Reynolds Numbers are calculated together with a table of results for lift and drag coefficient. Plots of lift and drag coefficient versus angle of attack are printed.

The student then estimates a value of lift coefficient for the full-scale airplane based on model and aircraft Reynolds Numbers. The student enters his estimated maximum aircraft lift coefficient, aircraft weight, and altitude. The program predicts the aircraft drag polar. Based on the drag polar, the thrust required and power required are tabulated for a range of velocities. The student may enter new values of aircraft weight or altitude and repeat Part III.

This program was very valuable, permitting the immediate reduction, plotting, and analysis of the test data. The student time to perform calculations and write a report was greatly reduced. This permitted the instructor to introduce additional wind tunnel tests or to teach more about laboratory instrumentation and measurements.

Electrical Engineering

A variety of programs similar to those listed under spot testing has been used in the basic electrical engineering course which supports the Aerospace Engineering curriculum.

An interesting and very successful computer program was developed to teach a student how to operate the oscilloscope.[8] The oscilloscope is one of the principal measuring and recording devices in the engineering laboratory. When performing exercises in laboratory work, students most often work in pairs and small groups. As is often the case, some students avoid working with or using the equipment and become the "data takers" and the report writers. As a result, some students never learn how to operate the equipment. Therefore, a program was set up to teach the basic operations of an oscilloscope with computer instruction and assistance. Each student carrel, Figure 5, was provided with an oscilloscope mounted above the teletype terminal, plus a battery-operated signal source which provided a variety of waveforms for investigation. An instruction pamphlet which contained a sequence of instructions to be executed or questions to be answered was given to each student. This material could have been typed out by the computer but the hand-outs were used to save time. The computer was informed by the student as he completed each instruction or answered each question. Student activity was controlled by the computer which reinforced or amplified his responses and, based on his response profile, directed his progress. The first student exposure to this technique was well received by the students. Students progressed through the program at different rates. The computer program, procedure, and technique is being improved and tested again with students. This method for teaching students how to operate selected pieces of laboratory equipment appears to be very promising.

Computer-Aided Instruction

Three one-semester college level courses (Thermodynamics, Electrical Engineering, and Physics[10]) are being set up for the time-sharing computer instructional system. Doing the work here is a team composed of faculty, systems analysts, programmers, educational specialists, and administrative personnel. The following course development procedures are being used:

    Course Selection
        Planning Meeting
        Course Authorization
        Team Notebooks Generated

    Course Definition
        Course Objectives
        Behavioral Objectives
        Test Criterion

    Lesson Development
        Lesson Identification
        Material Preparation
        Programming
        Pre-Test
        Revision

    Course Development
        Lesson Integration
        Pre-Test
        Revision

    Test and Evaluation
        Conduct Results
        Evaluate Results
        Revision

    Final Documentation

Considerable time and effort is required to define specific objectives for each unit of course material, to establish satisfactory criteria for determining if a student has met the objective, and to determine the best way of presenting the material.

Thermodynamics It is interesting to note the reason for selecting the Thermodynamics course. All non-engineering students at the Naval Academy are required to take a course in basic Engineering Thermodynamics. A higher level course is taught to engineering students. The ultimate goal is to have one computer-aided Thermodynamics course for all students. All students will be required to meet the same objectives, but will proceed through this material at their own pace. Upon completing this course, students in engineering will continue and will cover additional material in greater depth. This self-paced program illustrates what is perhaps the greatest promise of Computer-Aided Education. It makes it possible to accommodate the educational process to the two most significant student variables: intelligence (basic learning ability) and energy (motivation, industriousness, drive). In principle, it permits the student to master any subject to the limit of his ability.

The Thermodynamics CAI group, composed initially of two officers and three professors, met as a committee to organize their efforts at the beginning of the summer of 1967. The first order of business was to write complete course description in behavioral terms and to establish prerequisites. Next, a primary text was selected as a guide and for eventual issue to the students. The committee divided the course into segments, and identified the behavioral objectives within each segment by examining the topical coverage and then indicating for that topic the depth of coverage desired by checking the appropriate items on the following list:

    Knowledge
        Awareness
        Appreciation
        Understanding

    Application
        Sample Problem
        Simple Exercise
        Difficult Exercise

    Derivation
        Design Exercise
        Assumptions and Results
        Complete Derivation

Having completed the course coverage in this manner, the committee then broke up into one or two-man subcommittees to work on each segment. It had now become a committee of course authors. Work by each subcommittee on a segment consisted of writing the behavioral objectives, identifying criterion test items, and establishing criteria of success. When the subcommittees had completed a segment, the committee as a whole met as a "murder board" to discuss and approve it. A comparison of the text and objectives was then made and, if the comparison was favorable, the actual instructional material was put in flow-chart form. If the comparison indicated that the text was inadequate, the authors prepared their own written text for the questionable area and then proceeded with the development of the instructional material.

The development of the instructional material--the detailed pedagogical outline of each segment--was the most important function of the entire effort by the author group. Generally, this development consists of determining the strategy in flow-chart form to cover one or more objectives and then writing detailed instructional material which follows this strategy to the extent of selecting the media (CRT, IMAGE PROJECTOR, AUDIO, TTY, TV) and designing the interplay between them.

During the development of this material and the review and revision process, it became quite clear that, next to the material content, the selection and interplay of the media for presentation was very important. In addition, the importance and significance of each medium became clearer as experience was gained by both the author

and systems analysts. For example, the use of audio in short bursts with written and pictorial reinforcement was determined to be very effective.

Segments of the course are being reviewed continually by the authors and other faculty members. During the present Spring Semester of 1968, some of the students are actually using the completed CAI material in the course. Much work remains to be done to complete the course by the target date of September 1968.

Classroom

The CAI classroom is designed to accommodate twelve students in individual carrels arranged in a U-shaped configuration around 25' x 26' room. Each of the individual student carrels (4'6" wide, 4'0" deep, and 6'0" high) provides a total of 14 square feet of top space. The table surface is L-shaped to allow the student to sit inside the carrel. Among the twelve carrels, a mix of both right and left side tabletops was provided. Directly in front of the carrels, also in a U-shaped configuration, are 20" wide pedestal-type, continuous tabletops. Each student has a fiberglass swivel armchair so that when not working at the carrel he can turn 180° and work at the desk-high surface. Both the student carrels and the tables are on a 6" raised platform, under which are the computer and closed circuit television cables leading to each student carrel and the instructor's desk. The instructor's table is at the open end of the "U" with a chalkboard and retractable projection screen behind it.

Concluding Remarks

Although it is difficult to present a complete picture of the use of CAI in engineering education because of its limited use to date, it is still possible to make some significant general concluding remarks.

Computer-aided instruction should be viewed as a part of educational technology and be examined in terms of the total educational environment; i.e., classroom, laboratory, faculty office, dormitory, study area, and even administrative offices. Although it can certainly become as important as the blackboard has been as a classroom tool, it will never replace the teacher. It will definitely change his role, however. In addition to being required to establish more precise and measurable course objectives, the teacher will find himself in more of the role of a tutor, with important subroles as proctor and counselor. In other words, the teacher will spend more time talking to individual students, analyzing their progress, and planning their future courses with them.

The teacher's role as course author will also be extremely important. He will have to establish more precise and measurable course objectives than is current practice, and will be a member of the team that converts these objectives into CAI techniques. This makes it clear that preparation and training are essential in developing faculty strength in computer-aided education. The time and expense involved will be worthwhile because we will need teachers who are knowledgeable and who will be able to evaluate developments in this field in light of their own educational systems.

Testing of computer-aided instructional techniques must be carried out continuously. The results should be evaluated in terms of the established objectives, not in comparison with conventional methods.

Every attempt should be made to use effectively the two most important features of the computer—rapid computation and high-speed retrieval of stored information. The time saved in data reduction, curve plotting, report writing, and design calculations will be significant. The time saved in laboratory course work can be devoted to additional experiment or to increased emphasis on laboratory measurements and techniques. In a design course, a student can use the additional time to explore his overall design in much greater depth or to pursue several design concepts simultaneously.

Remote terminals will be a great asset in laboratory and design courses because of the immediate availability of the on-line computational power of a computer. The availability of remote terminals to students in the dormitory and study areas will increase the value of computer programs for drill, review, and homework problems. It appears that the use of remote terminals will make the case problem a more useful technique in the classroom.

Even at this early date, a significant pay-off of the computer-aided education program has been the increased computer awareness of both the students and the faculty. Students no longer view the computer as only a high-speed slide rule. Many more faculty members have become directly involved with the use of computers, have become aware of the computer's abilities, and have been stimulated to be more creative in their classroom approach.

Undoubtedly, the introduction of computer-aided instruction on any campus will result in a vastly more flexible and much-improved educational program for all its students.

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FIGURE 1. Remote Teletype Terminal - Model 35

FIGURE 2. Remote Terminal "Problem Solving" Experimental
Classroom

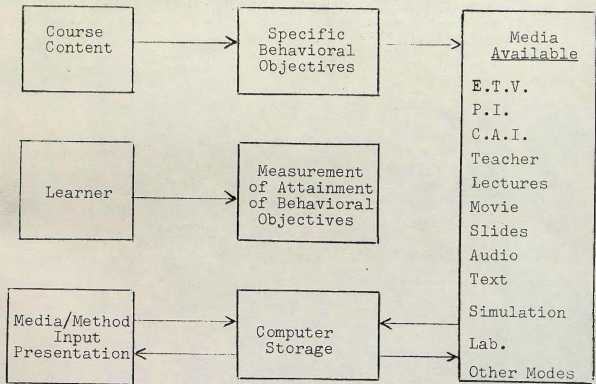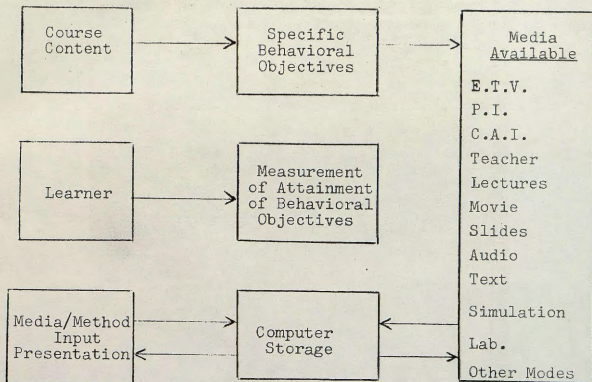FIGURE 3. Student Carrel - CAI Instructional System

FIGURE 4. Model for Single Course Development in Multi-Media

FIGURE 5.   Student working on program which teaches operation
            of oscilloscope

FIGURE 4. Model for Single Course Development in Multi-Media

FIGURE 5. Student working on program which teaches operation of oscilloscope