ChE curriculum

COMPUTER-BASED INSTRUCTION: IS THERE A FUTURE IN ChE EDUCATION?

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AS THE WORLD ENTERS the decade of the 1980's, revolutionary developments are continuing in many areas of human endeavor. Unfortunately, improvements in the delivery of university level education has been disappointingly slow. Even though some new tools like overhead and slide projectors, tape recorders and television equipment have been introduced into educational institutions, the basic form of teaching remains the traditional lecture.

Recent increases in enrollment in most chemical engineering departments have helped to indicate that the lecture method of educational delivery has some serious limitations. As course sections have become larger it is increasingly difficult, or even impossible, to personally interact with each student to aid in the understanding of the lecture material. Thus, the shortcomings of the lecture system are becoming painfully apparent. During a lecture the majority of the students listen passively while only a few students ask questions or actively answer questions. Studies in psychology [1] have shown that, for the average student, passive listening is a very ineffective way to learn.

In 1968 Dubin and Taveggia (cited in Kulik and Kulik [2]) reviewed all comparative research on college teaching methods conducted during the years 1924-1965. They found many studies that utilized final examination performance as a criteria of teaching effectiveness, and they concluded that no teaching methods were significantly better than the traditional lecture. Fortunately two developments that have been made since 1965 will have a direct impact on the delivery of educational materials. These are:

- **The Personalized System of Instruction, PSI.**
- **Computer-Aided Instruction, CAI.**

This paper will provide a summary of the essential characteristics of PSI and will provide a detailed overview of one of the most advanced CAI systems, the PLATO educational computer system. A consideration of the future of computer-based education which effectively combines PSI with CAI will be followed by a discussion of the current status and future use of PLATO in chemical engineering education.

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SELF-PACED INSTRUCTION

THE MERITS OF A SELF-PACED, or personalized, system of instruction (PSI) have become widely recognized since the initial concepts of this method of instruction were developed by Keller [3]. Many of the unique aspects of this type of course presentation are summarized in Table 1. An interesting collection of papers related to PSI has been published by Sherman [4]. There is no doubt that self-paced instruction provides a superior educational experience and is preferred by most students. Some of the strong points of PSI are:

- **Student responds and there is immediate reinforcement or feedback**
- **Student progresses at his own rate**
- **Material is presented in small carefully sequenced steps**
- **Program leaves a record leading to improvement**
- **Punishment is minimal**
- **Desired goals are defined and mastery is required**

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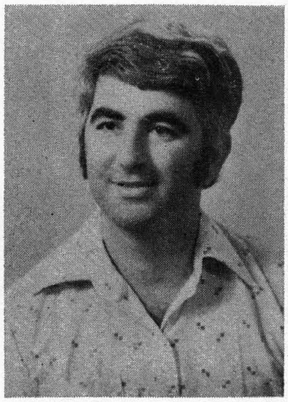 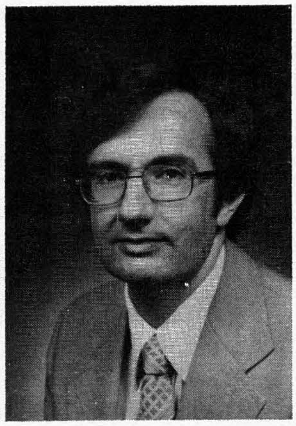

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At the University of Connecticut, Professors Howard and Stutzman offered a Process Dynamics and Control course via self-paced instruction in 1972 and 1973, but computer-based instruction was not used. A summary of the successful experience with this course has been given by Howard [5]. Unfortunately, the format of this course reverted back to the traditional lecture style of delivery because of two major difficulties: The increased work load on the instructors was exhorbitant, and class sizes began to increase and the necessary graduate assistants (tutors) were difficult to obtain. These problems have also forced others who prefer PSI to abandon it [6]. In addition, there are always a few students who fall behind, procrastinate and take incompletes.

Computer-based delivery of courses can retain most of the benefits of PSI while freeing the course instructor from repetitive administrative details and providing the student with an intelligent tutor.

Bitzer [7] has recently reviewed the development of CAI, and an excellent summary of CAI in chemistry is available (Lower et al. [8]). A recent report entitled "Computer Graphics in Chemical Engineering Education" [9] provides a summary of existing applications and a thorough discussion of current hardware and software, but this report is only concerned with computer graphics.

The following description is limited to one of the most available CAI systems, the PLATO system. This advanced educational system is widely used and seems to provide the greatest potential for extensive utilization in chemical engineering education.

THE PLATO SYSTEM

PLATO, an acronym for Programmed Logic for Automated Teaching Operations, was developed during a project started in 1959 at the University of Illinois. Since 1967, Control Data Corporation (CDC) and the Computer-based Education Research Laboratory (CERL) at Illinois have produced one of the first large-scale computer-based educational systems. Over six thousand hours of instructional materials are currently available in a wide variety of fields from interconnected PLATO computer systems located in Minnesota, Delaware, Florida, Texas, Illinois, Quebec and Brussels.

A schematic diagram showing the essential features of a PLATO system is shown in Figure 1. The system is typically composed of several central processing units (CPU), and a number of peripheral processing units (PPU) tied to the central memory (CM). The extended core storage unit (ECS) is a random-access electronic swapping memory which is tied directly to CM and the PPU's. The PPU's handle input and output to terminals and control mass storage units such as disks and tapes and other external I/O devices.

The new Delaware PLATO system [10] is based on a Control Data Corporation Cyber 173 computer. It is configured to service 100 simultaneous PLATO users, but this can eventually be expanded to 1008 users. The initial Delaware system has one

TABLE 1

Key Concepts of the "Keller Plan" for PSI

A. **Individually Paced**
  - **divided into 15 to 20 units**
  - **detailed study guides provided**

B. **Mastery Oriented**

C. **No Punishment for Failure**

D. **Proctors Deliver Course**
  - **repeated testing**
  - **immediate scoring**
  - **unavoidable tutoring**
  - **provide personal/social aspects**

E. **Stress upon Written Materials**
  - **lectures optional**

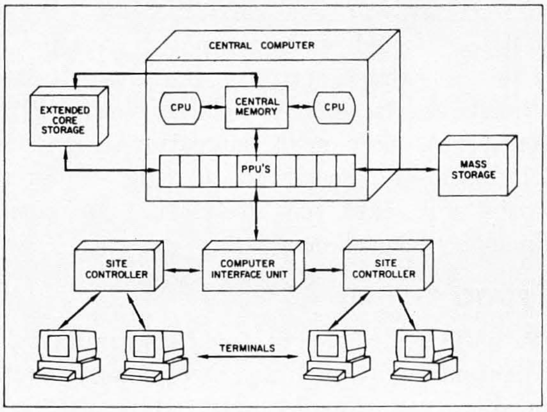

FIGURE 1. PLATO computer system configuration.

CPU and ten PPU's operating with 98,000 60-bit words of central memory. In addition, 500,000 words of extended core storage, four dual-density disk drives, two tape drives and two remote job entry stations are utilized.

The computer interface unit provides data communication between the central computer and up to 32 site controllers. The site controller processes two-way digital data between the computer interface unit and the PLATO terminals. The link to the terminal may be via direct connection or phone line. In some cases, output data to the terminals may be multiplexed onto a standard TV channel by the computer interface unit for efficient transmission via microwave or cable to the site controllers [7].

THE TERMINAL

The PLATO terminal available from Control Data Corporation consists of a video-scan cathode ray tube (CRT), a touch panel on the CRT, and an electronic keyboard. The CRT display panel contains a matrix of 512 by 512 separately addressable points. Display memory storage and logic control of the terminal is provided by a micro-processor located within each terminal. The touch panel on the CRT display is capable of sensing any one of 256 positions which allow very convenient user input to the system. Normal input is via the keyboard unit which has 64 keyswitch locations and is based on the typical typewriter configuration. In addition, two sets of arithmetic keys and special control keys are provided. Since the PLATO system interprets individual key selection before they are displayed, authors can generate their own set of 126 characters (such as Greek letters and special symbols like ΔT, °C, ϵ etc.).

When a PLATO lesson is requested by a user at a terminal, it is transferred from the disk unit of mass storage to the extended core storage, where it remains while in use. Programs and data in the ECS are transferred in and out of central memory during lesson execution. This rapid transfer rate of the ECS makes possible a maximum response time of 0.25 seconds to each terminal user.

A number of accessories can be attached to the terminal. These include a random access audio device, color microfiche slides, hard copy printers and floppy disks. Other devices can be electronically connected to PLATO such as carousel projectors, oscilloscopes, electronic test equipment and even laboratory instrumentation.

IMPORTANT FEATURES OF PLATO

Ease of use

Neither the students nor the instructor need to have any previous computer experience. All that is required is an ability to use the typewriter keyboard. Lessons are available for terminal instructions once the user is shown how to log onto the system. Only five to ten minutes of terminal time is required to learn to use the terminal.

System flexibility

The terminal users may work on different

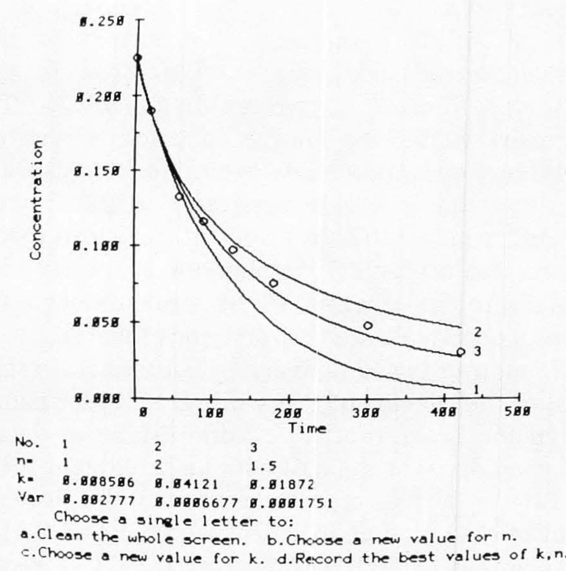

FIGURE 2. Determination of the reaction order and rate constant from experimental data using PLATO.

The CMI system analyzes the students' current status, what units of the course he has already mastered and in which areas he has had difficulties . . . The instructor has immediate access to the student records and can easily do any type of statistical analysis of student performance.

lessons at the same time. It is possible for some of the terminals to be used by students taking lessons at the same time that others are used by authors preparing or revising lesson material.

Student/instructor interaction

The terminal users can communicate via the PLATO system. For example, a student may ask a question by typing in the identification code of his instructor and his question. The instructor can respond immediately if he is working at a terminal at the same time, or the next time he signs on a terminal. The instructor may even look at the students display or show him something which is on his display. Their geographic locations can be thousands of miles away from each other.

Use of the computer as a calculator

It is possible to use the terminal as a calculator in any stage of the lesson execution. For typical problem solving in an engineering course, this feature conveniently allows a student to make intermediate and final calculations. A major advantage over the hand-held electronic calculator is that the entire function being evaluated is retained on the terminal display.

Touch response

The touch sensitivity of the PLATO terminal panel adds a new dimension to the capabilities of CAI. In Figure 3, for example, the touch panel is used for minimization of an objective function of two variables. The student touches the area which seems to be most promising as a possible minimum, and PLATO evaluates the objective function value at this point. The touch panel has also been used to "synthesize" complex molecules from simple ones, to test the student familiarity with diagrams and to simulate laboratory experiments.

Graphics

The graphic and animation capabilities of PLATO add greatly to the effectiveness of CAI. For example, when the student tries to fit reaction

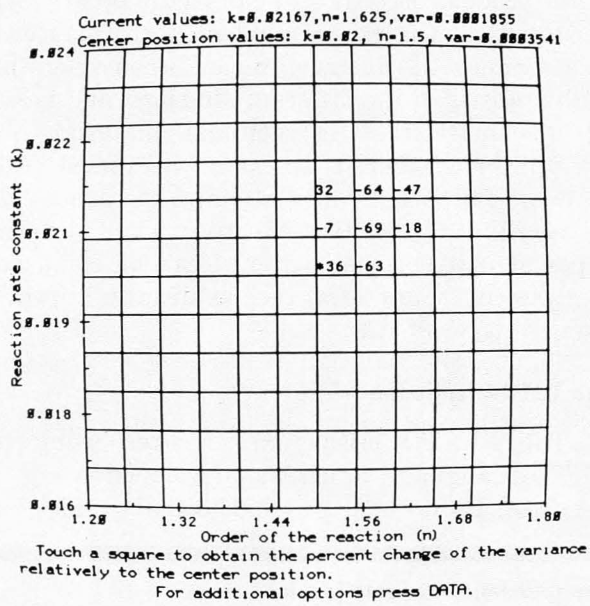

FIGURE 3. Minimization of a function of two variables using the touch panel.

rate constants and orders of reaction to experimental data in a kinetics lesson, he gets both visual and numerical feedback regarding the goodness of fit (see Figure 2).

Analysis of the student's response

One of the more critical aspects of any CAI system is the one that analyzes and judges the students' responses. Nothing can be more frustrating for the student than the rejection of his correct answer because he did not enter it in the form anticipated by the author (for example, by writing 0.333 for 1/3). The PLATO system can recognize numeric matches independent of format and can separate the numeric part of the answer from the non-numeric parts (when both the numerical value and the units of the answer should be checked). It can indicate mispellings, incorrect answers or incorrect order of words in sentences.

Computer managed instruction (CMI) system

This software system keeps track of the progress of each individual student as well as on the progress of the whole course. The CMI system analyzes the students' current status, what units of the course he has already mastered and in which areas he has had difficulties. Prescriptions for lessons to help achieve mastery learning can be automatically generated on the basis of appropriate testing. The instructor has immediate access to the student records and can easily do any type of statistical analysis of student performance. In this manner the instructor can become familiar with abilities of the different students, and he can also evaluate the instructional material. For example, when there is an exam which most of the students fail at their first attempt, the exam must be too difficult. Relative effectiveness of different types of instructional material can be compared, and the course material can be steadily improved using this feedback.

The TUTOR language

The PLATO lessons are written using the TUTOR language which was developed solely for CAI use. Its developers tried to make the lesson

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writing as simple as possible. The most impressive parts of the language are those dealing with graphics, animation and student response analysis. Sophisticated effects can be generated by relatively simple and short coding. It should be noted, however, that for engineering education the calculational capabilities of the TUTOR language are somewhat limited.

Basic knowledge of the TUTOR language can be attained with about 85 hours of training, even for those who have no previous programming experience. But, of course, additional study is necessary to use most of the TUTOR capabilities effectively

The development of the courseware for university level education is limited at the present. Many separate lessons in chemistry, physics, mathematics and other areas have been developed at the University of Illinois and several other universities but only limited experience in the development of a completely computer-based course has been attained. When used in the classroom, most current PLATO lessons either replace the regular homework assignments or simulate laboratory experiment to provide the background for the actual experiments in the laboratory.

College students who have had the opportunity to use PLATO are very enthusiastic about it. Their opinion is that they have learned more, in a more enjoyable way, than they would have through traditional methods.

PLATO IN CHEMICAL ENGINEERING

THE MOST ACTIVE AND ADVANCED development of chemical engineering lessons via PLATO is currently in progress at the University of Illinois under the direction of Prof. Charles A. Eckert. A complete set of lessons is being used with a first chemical engineering course entitled "Introduction to Chemical Engineering."

PLATO lessons at Illinois replace only some of the homework in a traditional lecture-recitation type course. Students are required to complete conventional homework assignments. PLATO is not presently used for any examinations. Professor Eckert [11] believes "that the major effectiveness of the PLATO lessons is in permitting students to do a wider variety of problems in a short time with instantaneous interaction in a nonintimidating manner."

At Illinois, well-written lessons prove to be excellent motivators, and the students do the available lessons with a very high completion rate. Students spend approximately 2/3 of their time on new PLATO lessons and about 1/3 of their time reviewing materials in preparation for examinations. Performance on examinations has dramatically increased since the introduction of the PLATO lessons. This success has prompted Prof. Eckert to begin working on a set of lessons for a first course in chemical engineering thermodynamics as well as some lessons on unit operations. Clearly, Prof. Eckert is very enthusiastic about the future of PLATO.

The University of Delaware originated a PLATO project in the Fall of 1974, and university-wide use of PLATO was sufficient to justify the purchase of a PLATO system in 1978 [10]. Chemical Engineering activities began last year under the direction of Professors Stanley Sandler and Robert Pigford. Professor Sandler is developing PLATO lessons for several types of chemical engineering thermodynamics problems that have been troublesome for weaker students. Professor Pigford is interested in lessons on material and energy balances.

In addition to the chemical engineering lessons discussed above, there are some lessons in related areas available on the PLATO system. These lessons can be used for reviewing background material in Chemistry, Thermodynamics and Numerical Analysis. There are some lessons which can make problem solving easier and make it possible to get an immediate graphical representation of the solution. There are explicit and implicit function plotters, a differential equation solver and a lesson for root locus and frequency response graphical plotting. Thus, even though the present number of available chemical engineering lessons is limited, the PLATO terminal can already be a considerable aid to the education of chemical engineering students.

A COMPUTER-BASED COURSE IN CHEMICAL REACTION ENGINEERING

AT THE UNIVERSITY OF Connecticut, we are directing our initial effort in the area of chemical reaction engineering. We plan to prepare PLATO materials over the next several years so that we can eventually offer a completely self-paced course to undergraduate students with computer-based instruction. This course was chosen because of the highly mathematical nature of the subject material. It has traditionally been taught with considerable use of computer programming for problem solving and simulation.

The course material will comprise the following:

- **A CMI Router which gives the student his assignments according to the material which has been completed.**

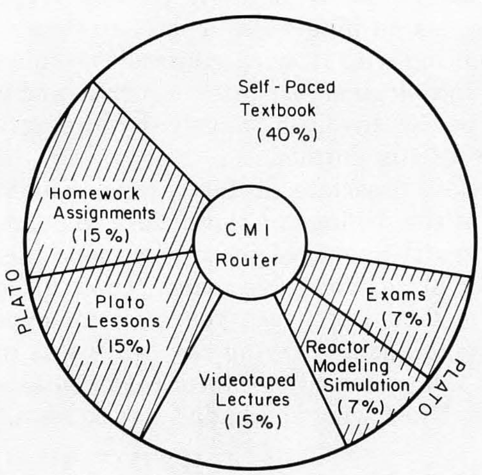

FIGURE 4. Structure of the computer aided CRE course.

The more basic courses in chemical engineering . . . will eventually be offered as self-paced computer-based courses delivered on interactive graphical computer terminals and utilizing self-paced textbooks, video cassettes, audio cassettes and film strips.

- **A Self-Paced textbook (probably the textbook by Fogler [12]).**
- **PLATO tutorial lessons for the more basic material.**
- **Homework assignments on PLATO.**
- **Examination questions and problems on PLATO.**
- **Reactor modeling and simulation requiring numerical analysis via PLATO.**
- **Video-taped Lectures.**

The proposed structure of the course and an approximation of the division of the student's time between the different activities is shown in Figure 4.

We at Connecticut feel that the present PLATO capabilities with the acknowledged benefits of self paced instruction will result in a greatly improved learning experience for our students.

LOOKING TOWARD THE FUTURE

COMPUTER-BASED EDUCATION will initially develop as a means of providing supplementary materials to the more traditional lecture format courses. In the laboratory, more and more of the laboratory experiments will be set up and simulated on interactive graphical terminals before actual work is undertaken. Many difficulties will be associated with the transfer of course materials among universities because of hardware differences and software incompatibilities. The reluctance of some faculty members to use someone else's computer-based materials will be a substantial barrier to the implementation of computer-based materials.

The introduction of computer-based materials will be initially resisted by most of the professors, but enthusiastically greeted by the students who prefer many aspects of this type of coursework delivery. State legislatures will support the initially high costs of computer-based instruction because this type of delivery will allow the efficient delivery of many introductory courses into every community college, state college or university branch campus in the state.

The more basic courses in chemical engineering such as Material and Energy Balances, Thermodynamics, Process Dynamics and Control, and Reaction Kinetics will eventually be offered as self-paced computer-based courses delivered on interactive graphical computer terminals and utilizing self-paced textbooks, video cassettes, audio cassettes and film strips. Student exposure to completely computer-based courses will be limited to one, or at most two, per university term. Faculty will continue to teach advanced undergraduate and graduate courses in the traditional lecture mode, and they will have more time for research and personal interaction with students. □

ACKNOWLEDGMENTS

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Continued from page 60.

heartedly around the neighborhood from time to time. He immersed himself in running, rarely missing six to nine miles a day, studying it, experimenting with it, wiring himself up to measure what physiological responses occurred, and getting other people involved, mostly by the infectious quality of his enthusiasm.

A close associate at Los Alamos summed up many of the feelings of those close to John. "You have been truly one of those who made the world a better place. You gave many people a model of how life should be lived: your zest for experiencing new things and trying new ways was inspirational. I am intensely grateful that you came into my life. I just wish you hadn't left so soon."

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U. of Florida