ChE classroom

A FLEXIBLE SELF-PACED COURSE IN PROCESS CONTROL

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A REQUIRED PROCESS control course has been taught for the past three years by a self-paced instructional method [1]. The course content consists of the traditional process control concepts along with process dynamics, analog and digital simulation, and a laboratory. In the past, many students seemed to have difficulty achieving a satisfactory grade in the course. Part of the reason for the difficulty may have been the cumulative nature of the course and the fact that it is a last semester course when course work must compete for a student's interest with the selection of a job or graduate school.

Because of the cumulative nature of the course content, it is imperative that the students master virtually all of the material as they proceed. The mastery learning requirement is the very core of the Keller plan or self-paced instruction. Students are not allowed to proceed until they demonstrate a mastery of the required course material. The self-paced nature is also timely for seniors who are often taking plant trips. In addition, the method emphasizes learning separate from a lecture. There were no lectures for this course, but audio tapes were available for students that preferred that mode of getting information.

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Since most chemical engineers do not become control or instrumentation engineers, it seemed reasonable to allow students to select material they wish to master. The course began with requiring that all students acquire a mastery of Laplace transforms and process dynamics. The student was then presented with a choice of selecting the topics for the remainder of the course from units in process control, analog simulation, digital simulation or a laboratory project.

INSTRUCTIONAL METHOD DESCRIPTION

THE KEY FEATURES OF the Keller plan are listed in Table I. All of these features were used. Several of the difficulties in using the Keller plan are student procrastination, a fixed curriculum, the lack of available self-study materials for chemical engineering courses and the time required for preparing multiple exams. Table II lists the features used in the control course at Howard University.

An extensive amount of time was spent in organizing the course into a hierarchy of modules and in developing self-study materials.

TABLE I
Features of the Keller Plan

Modular Course Structure
Self-Paced
Mastery Learning
Lectures for Motivation
Stress on Written Materials
Use of Peer Proctors

The material for each study unit consisted of a study guide, an audio tape of lecture material and supplementary material which varied among the units. The study guide consisted of a title, a set of objectives, the required work and a list of skills to be mastered to complete the unit. The list of skills was also important because it told the student exactly what he was expected to learn. All questions and problems on the criterion tests were based on the required list of skills.

A key to instructor survival in any self-paced course lies in estimating a student's readiness to take a quiz. Since students could repeat quizzes without penalty, it was imperative that a method be devised to assure that students were prepared before they took the quiz. The method used was also designed to motivate the students to be well prepared. As part of the required work on each unit, each student was required to formulate and solve a criterion test based on the skills to be mastered in the unit. If the instructor determined that the student's test showed both readiness and mastery learning, the student was awarded an exemption from a further test.

Students were allowed to take unit exams whenever they had completed all the required work satisfactorily. Students were asked to submit their required materials on the day before they expected to take an exam so that the instructor or proctor could check their work. If a student did not receive a passing grade, generally an A, he was allowed to repeat the exam as many times as needed without penalty. Students were restricted to taking one exam on any unit per day.

The final grades for the course were based on the number of points each student accumulated by the end of the semester. A student had to accumulate 90 points to receive an A, 80 points for a B, etc. Most of the study units were worth four points and the passing grade was an A. Students were awarded full credit on units completed with an A grade. On certain units, and laboratory reports, the passing grade was B or C because progress through the course was not hampered by the lower level of mastery. However, if a student achieved a B, he was awarded only three points. Two points were given if his passing grade was a C. Students were encouraged to work on a number of units simultaneously. They were told that they should be working on a text unit, a computer unit, a laboratory unit, and their project simultaneously.

One of the problems with self-paced instruction is procrastination. For the past two years incentive plans were used to motivate the students and to reduce procrastination. In 1977, the plan was in effect for a three week period. During the time that the plan was in effect, a student was penalized two points during each week they failed to complete a unit. They were also awarded two points or five points if they were able to complete two or three units, respectively. The incentive plan was modified in 1978 and was in effect for the entire semester. The modified plan eliminated the five point bonus and specified that a maximum of ten bonus points could be earned.

TABLE II
Process Control Course Features

All Features of Keller Plan
Course Graded By Accumulated Points
Flexible Curriculum
Detailed Module Information
Alternate Sources of Information
- **Text**
- **Audio Tapes**
- **Instructor**
- **Proctor**

Motivational Tools

COURSE DESCRIPTION

THE COURSE WAS divided into 36 units or study modules and was based primarily on the text "Process Systems Analysis and Control" [2]. The

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flow of material parallels the text. In fact, many of the units consisted of a chapter from the text. Table III lists the study units that were used in 1978. A hierarchy of units is shown in Figure 1. The units on Laplace transforms were supplemented by material from Strum and Ward [3]. The units on experimental determination of dynamics and control loops heuristics were supplemented by material from Luyben [4] and Perlmutter [5]. Table IV gives sample study guides for two of the units.

Since the method of instruction was new to most of the students, the first unit consisted of having them learn about the self-paced method and how the course would be taught. The introductory unit was included as a motivational tool and because of the topic's importance to the course. The unit was designed to have the students complete a unit quickly and begin earning points on the very first class day.

During the course of the semester, several movies on process control were shown along with industrial presentations, and lectures on selected topics. A movie summary unit was included. To receive credit for the unit, a student had to submit a written summary of the activity, in memo-

TABLE III
Process Control—Study Units, Spring 1978

No.	Title	Text: Ref.	Prereq. Unit	Min. Pass. Grd	Max. Pts.
0	Personalized System of Instruction	Tape		A	2
1	Laplace Transform	Notes; Ch 2	0	A	4
2	L.T.—Further Operations	Notes	1	A	4
2A	L.T.—Disturbances and Building Functions	Ch 3, 4	2	A	4
3	Intro. and First Order Sys.	Ch 1, 5	2A	A	4
4	Physical Examples	Ch 6	3	B	4
5L	Sensor Dynamics Lab.	Handouts	3	C	4
6L	Mixing Tank Dynamics Lab.	Handouts	4	C	4
7	Systems in Series	Ch 7	4	B	4
8	Higher Order Systems	Ch 8	7	A	4
9	Elements of Control Sys.	Ch 9, 10	8	A	4
10	Ideal Controllers and	Ch 10, Notes	9	A	4
11	Block Diagrams	Ch 11, 12	9	A	4
12	Transient Response of C.S.	Ch 13	11, 10	B	4
13	Stab. and the Routh Test	Ch 14	12	B	4
14	Concept of Root Locus	Ch 15	13	B	4
15	Transient Response from RL	Ch 16	14	C	4
16	CS Design from RL	Ch 17	15	C	4
17	Computer Program—LOCUS	Notes	14	A	4
18, 18A	Frequency Response	Ch 18, Notes	13	B	4, 4
19	CS Design by FR	Ch 19	18	C	4
20	Computer Program—BODE	Notes	18	A	4
21	Closed loop resp. using FR	Ch 20	19	B	4
22	Nyquist Stab. Criterion	Ch 21	18	B	4
23	Exp. Det'n. of Dynamics	Notes	12	A	4
24	Controller Tuning; Control		12	A	4
25	Intro. to Analogs	Handouts, Ch 30	3	A	4
26	Analog Computer Scaling	Handouts	25	C	
27L	Use of Analog Computer	Handouts	26	B	
28	Simulation of Dynamic Sys.	Ch 32, Notes	11, 25	B	4
29	LEANS Simulation	Notes	29	A	
30	Control System design study using LEANS or Analog	Notes	10 and 29	B	6
31	Movies summaries		—	—	6
32	Spec. of Control Valves		10	A	4
33	Cascade Control		13	A	4
34	Laboratory Project			A	≤8
35	Oral Pres. of Unit 30 or 34			—	4
36	Course Improvement Paper		—	—	2

. . . the first unit consisted of having them learn about the self-paced method and how the course would be taught. . . . The unit was designed to have the students complete a unit quickly and begin earning points on the very first class day.

randum form, within 24 hours after the movie was scheduled. Students received up to two points for each summary they chose to submit.

DISCUSSION AND RESULTS

BY FAR THE MOST significant result was that the students were learning more process control than they had in previous years using the lecture method. Using final grades for the course as a measure of achievement, the summary below indicates the dramatic increase in learning as a result of using the flexible, self-paced method:

	% OF STUDENTS RECEIVING GRADES	
	A or B	D or F
1973-75 using the lecture method	28	31
1976-78 using flexible, self-paced method	77	3

It is interesting to note that the one student who failed to succeed with the method was an honor student. The student failed the course because of personal reasons and did not attempt to participate in the course.

Having students prepare and solve a criterion test proved to be an effective motivational tool to get students to be prepared for the unit exams. It also was the means of controlling the number of exams that had to be given. In 1977 there were 15 students in the class and 288 exams were given! Over the past three years, 1.2 exams were given per unit per student. In other words, approximately 80% of the time the student achieved an

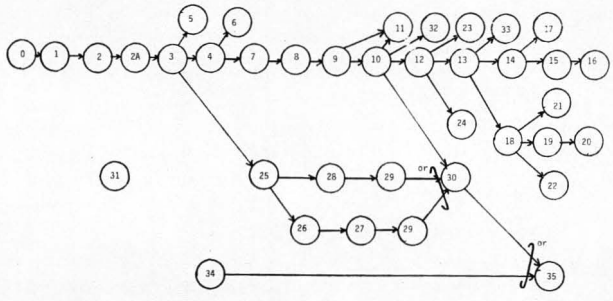

FIGURE 1
Hierarchy of Units For Process Control

FIGURE 2 CUMULATIVE CLASS PROGRESS

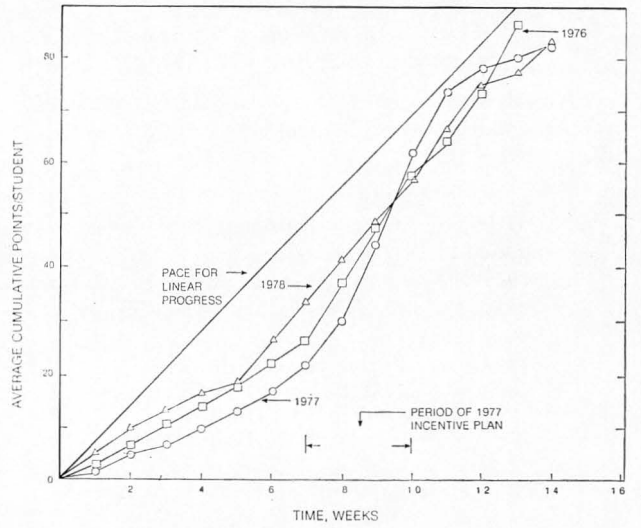

FIGURE 2
Cumulative Class Progress

A on the quiz and did not have to repeat the quiz. Most students passed the quiz on the second try, but there were several cases when a quiz had to be repeated more than once.

During the past two years, 9% of the students received exemptions from the quizzes. Many students felt that an exemption was too difficult to attain and appeared to stop trying. In the course evaluation at the end of the semester, many students felt that the requirement of having the student prepare and solve an exam should be dropped because it was too much work. Because of the dual purpose of the procedure, however, I plan on continuing the requirement.

Figure 2 is a curve which shows cumulative class progress in the self-paced course over the past three years. A curve for linear progress toward a final grade of A is also included. The carrot-and-stick incentive system was not used in 1976. The system was started in 1977 because the students' progress was lagging behind that of the previous year, mainly because of pressures by other instructors. The incentive program had a dramatic effect in productivity during the three weeks it was in effect. During this period there was nearly 200% increase in the number of units

completed per student per week. A word of caution must be noted when using this type of program. The students aim to earn bonus points. In 1977, several students earned as many as nine bonus points and half of the class earned the full ten points in 1978. The large number of bonus points awarded "appears" to have the effect of increasing the students' point total by a full letter grade. The actual effect was negligible, however, since the earliest course curriculum contained four units that were worth six points and were reduced to four points during the years the incentive systems were used.

TABLE IV
Study Units In Process Control
Study Unit 0, Spring 1977 (King)

TITLE: Introduction to PSI (personalized system of instruction) and Process Control
REQUIRED WORK:

1. **Listen to the tape on PSI.**
2. **Participate in a class discussion of the method as applied to the PC course.**
3. **Study the general information for the PC course.**
4. **Prepare a written summary of the criterion test items below.**
5. **Prepare a criterion test (with answers on a separate page) of at least 3 questions.**

CRITERION TEST ITEMS:

1. **Name author and title of course text.**
2. **Name the inventor of the PSI method.**
3. **Tell what PSI stands for.**
4. **List 5 characteristics of the PSI method.**
5. **Define: mastery learning, peer proctor, learning unit.**
6. **How is the course graded?**

OBJECTIVE: To introduce the student to the personalized system of instruction and to learn how it will be used in the process control course.

Study Unit 14

TITLE: Root Locus Methods
PREREQUISITE UNIT: 13
OBJECTIVES: To determine the actual roots of the characteristic equation of a control system by a graphical, root locus, procedure.
REQUIRED WORK:

1. **Read and outline chapter 15.**
2. **Prepare a criterion test with solution.**
3. **Complete the homework assignment: 15.1, 15.2a, 15.4c.**

CRITERION TEST ITEMS:

1. **State and apply magnitude and angular criteria.**
2. **Identify: branch, loci, zero, pole.**
3. **List the rules of thumb concerning RL diagrams.**
4. **List the rules for rapid plotting of root locus diagrams.**
5. **Plot the root locus diagram using the rapid plotting rules.**
6. **Test a point using the magnitude and angular criteria to determine if the point is on the root locus diagram.**

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Teaching a course by the self-paced method requires considerably more instructor time than a lecture course. When a self-paced course is being developed, a great deal of time is required to design modules, construct exams and prepare tapes and supplementary materials. It has been my experience that the self-paced process control course requires three times as much time than when it was taught by the lecture method. A significant reduction in instructor's time can be achieved by having a proctor check materials, give exams and grade exams. Since chemical engineering at Howard University is undergraduate only at the present time, I have been having selected juniors take the course and then serve as proctors the following year. Unfortunately, these peer proctors have reduced the instructor's time only slightly because they generally are reluctant to evaluate their classmate's work.

An important part of the success of a self-paced course is the active participation of the instructor. The instructor must learn to thrive in his role as an educational manager rather than the usual role as a lecturer. In my experience I have found that the students responded well when they saw the instructor take an active role with students in various stages of the course. A self-paced course is doomed to failure if the instructor sits back and waits for students to completely act on their own. □

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