ChE classroom

INSTRUCTION BY THE PSI METHOD IN A REQUIRED SENIOR COURSE

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THE PSI METHOD of self-paced instruction introduced by Keller [1] has been gaining favor in higher education. Courses are being taught by this method at more than one hundred institutions. The National Science Foundation has sponsored PSI workshops, and the Center for Personalized Instruction was organized at Georgetown University in Washington, D.C. a little over a year ago. The American Institute of Chemical Engineers is becoming involved through the Modular Instruction Task Force—a subgroup of the CACHE Committee—sponsored by the National Academy of Engineering.

There are three important features of the PSI method—mastery orientation, self-paced study, and individual attention. Instruction is based on all students mastering all of the course material. How well this is achieved will be indicated by data showing the results from two years of the course operation. The students learn at their own rate from a textbook, from supplementary material prepared by the instructor, and by consulting with their fellow students and with staff members. The course material is divided into study units, and each student receives a study guide for each unit. The study guide contains a list of objectives for the unit, a suggested study procedure, and some questions or problems. When the student decides that he has satisfied the objectives for a unit, he asks for a quiz. The quiz covers all the objectives of the unit. The quiz is graded immediately when the student finishes.

As in many courses taught by the PSI method, a few lectures are given to stimulate interest and for general information. These lectures do not deal specifically with any of the course objectives.

TABLE 1
CM416 Process Dynamics and Control

1. Ordinary differential equations
2. Feedback control systems
   a. Conservation of mass and energy
   b. Feed back
   c. Block diagrams
3. Laplace transform techniques
4. First-order system response
   a. Transfer functions
   b. Time constants
5. Higher-order system response
6. Closed loop system operation
7. Control valves and controllers
8. Closed loop system response
9. Analog computer techniques
10. System stability
11. Root locus plots
    a. Stability
    b. Response

In order for a student to pass a quiz, the work must be entirely correct. The student is allowed to correct minor errors which he discovers during the grading process. If a student does not pass a quiz, another quiz covering the same objectives may be taken after a suitable study period. The instructor does not transmit information by lecturing and is free to help individual students who have learning difficulties or who have questions about the course material. These general features of the PSI method are often modified to fit the needs of individual courses or instructors.

At Michigan Tech, the PSI method was chosen for the process dynamics and control course, because it simulates the employment environment much more closely than does a course given using a lecture format. In an employment envrionment, people learn at their own rate by reading and by consulting with colleagues. The course in question is based on the text by Coughanowr and Koppel [2] and comprises the mixture of mathematics, response topics, and hardware topics usually covered in a ten-week term. A brief outline of the course is given in Table 1. This course is a required course for

senior ChE students. Since it is offered only once each year, students have good incentive to complete the course. In this respect, it is just like any other senior ChE course at Michigan Tech. This required course is followed by an elective course covering frequency response analysis, controller construction, and advanced topics. The elective course is taught using the normal recitation method, and there is a laboratory associated with it. The unit operations course is recommended as a prerequisite for the first course, but third year ChE students and electrical engineering students have completed the course successfully.

Tutors are available ten hours each week for quizzing and consultation. Students enrolled in the course usually are unable to use all of the available hours because of conflicts with other courses. There is a paid graduate teaching assistant to help with grading and course administration. Students enrolled in the course may also serve as tutors if invited to do so. The grading load is heavy, and assistance is necessary for

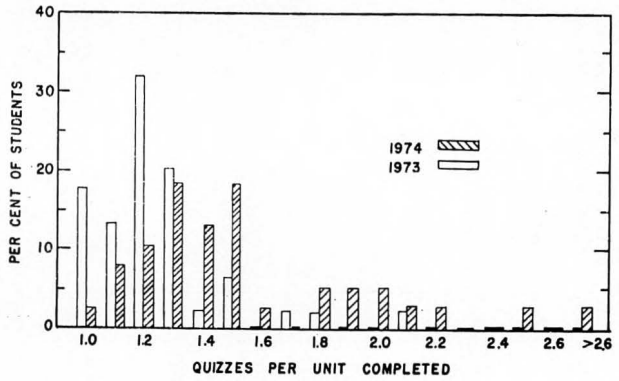

FIGURE 1. Frequency Chart for Quizzes per Unit.

smooth administration. More than 600 individual quizzes must be graded for a class of 40 students. This means that using the PSI method is quite time consuming. Figure 1 shows data for the number of quizzes taken per unit. Most students seem to take between 1.0 and 1.5 quizzes per unit. The mean was 1.2 in 1973 and 1.6 in 1974. This indicates some false starts but not too many. Students apparently are diligent in their study before requesting a quiz. They do not seem to take a quiz just to determine the nature of the questions.

A FEW LECTURES

AS IN MANY courses taught by the PSI method, a few lectures are given to stimulate interest and for general information. These lectures do not deal specifically with any of the course objectives. Typical lecture titles for the process dynamics and control course are "The Flyball Governor" and "The World Model." Only students who have completed a specified number of units are eligible to attend the lectures. About 50 percent of the eligible students attend the lectures. The rest prefer to work on the study units.

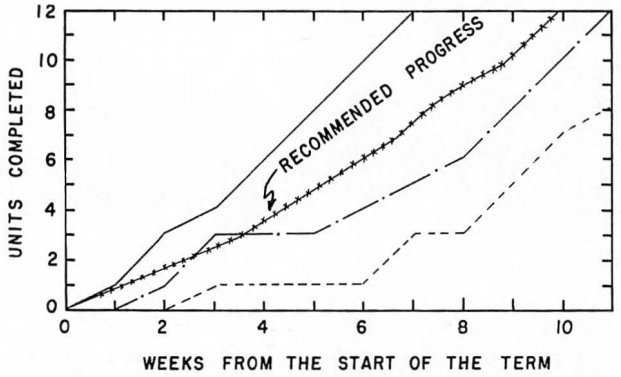

FIGURE 2. Progress Chart for Three Individual Students (1974).

All course activities are terminated at the end of eleven weeks—ten weeks plus one week for final examinations. At the end of this time, all students must take the final examination, and all students receive a course grade. Having this constraint means that the course is not completely self-paced. The time limitation simulates a deadline which often occurs in an employment environment.

The wide variation in the rates at which individual students progress through the course is shown in Figure 2 where the progress charts for

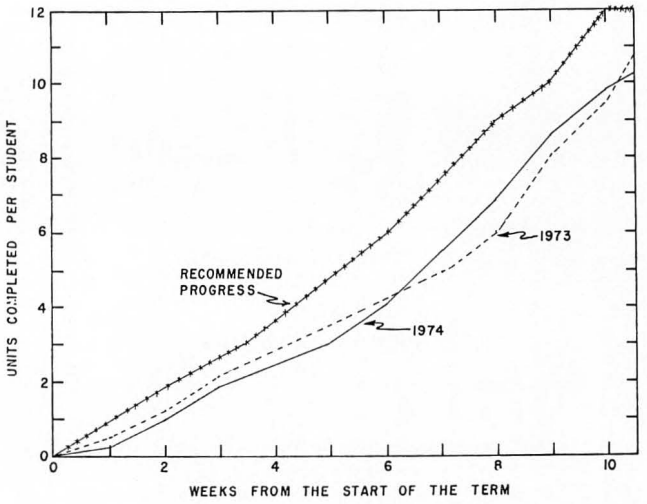

FIGURE 3. Mean Progress for the Class.

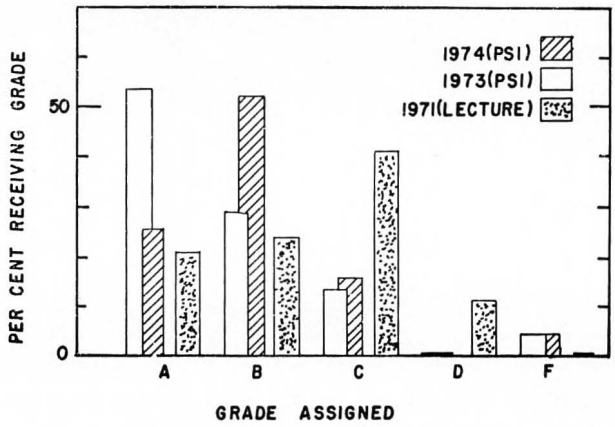

FIGURE 4. Grade Distributions.

three different students are plotted along with the recommended progress. The average progress for the class is shown in Figure 3 along with the recommended progress. It is typical of PSI courses that the average progress falls short of the recommended progress. For example, Philippas and Sommerfeldt [3] find this for an elementary physics course. The data in Figure 1 show one interesting thing. In 1973, no penalty was assessed for units completed late. General student opinion was that there ought to be a penalty for being late. In 1974, a mild penalty was established. The data for the average progress show that the penalty had little effect.

Grades are assigned according to the point scale shown in Table 2. An "A" is awarded if a student obtains 85 percent of the maximum

TABLE 2
CM416 Grading Scale

A+	200
A	171
B	128
C	96
D	63
F	63

number of points, a "B" if a student obtains 63 percent, a "C" for 49 percent, and a "D" for 31 percent. The system for awarding points is shown in Table 3. This point system seems to provide

TABLE 3
CM416 Point System

Pass a study unit	+10
Pass a study unit early	+1
Pass a study unit late	−1
Assist as tutor (2 hours)	+1
Final Examination	$\frac{\text{(Score x 68)}}{100}$

a balance of incentive and penalties which stimulate most students to progress through the course at a reasonable rate. Having a penalty associated with passing a unit late means that the course is not truly a "Keller Plan" self-paced course.

INCREASED COMPETENCE

THE GRADE DISTRIBUTION data reported in Figure 4 show that there is an overall increased competence at the end of the course compared to the same course taught by the lecture method in 1971. The grade distributions show one effect of the penalty for completing units late. When no penalty was assessed in 1973, there were roughly twice as many A's awarded as B's. The

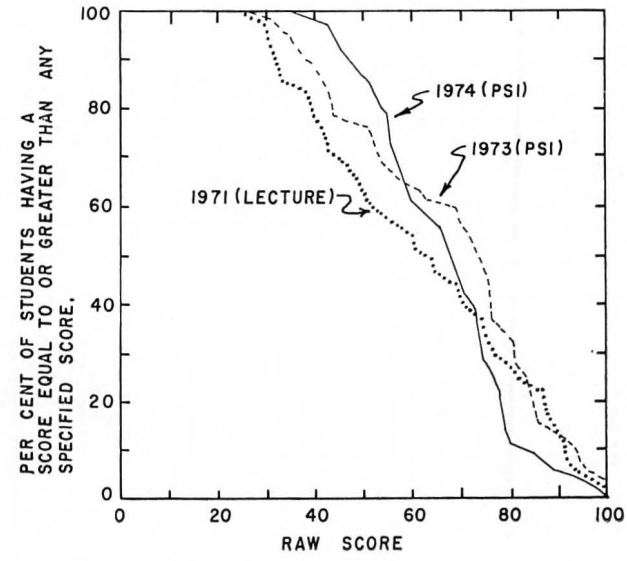

FIGURE 5. Final Examination Raw Score Distributions.

situation is exactly the opposite for 1974 when the penalty was begun. The grade distributions also show an effect which may be typical of required courses taught by the PSI method compared to required courses taught by the lecture method. For a PSI course, a greater number of students earn A or B than for a lecture course. For a PSI course, which is required in the curriculum, the number of students earning F is small but significantly greater than for a lecture course. It may be that in a lecture course students who have difficulty working independently will learn something just by attending class. These students will be unable to begin in a PSI method, can drop the course if they are unable to get started. The drop rate for the required process dynamics and control course is between six and twelve percent

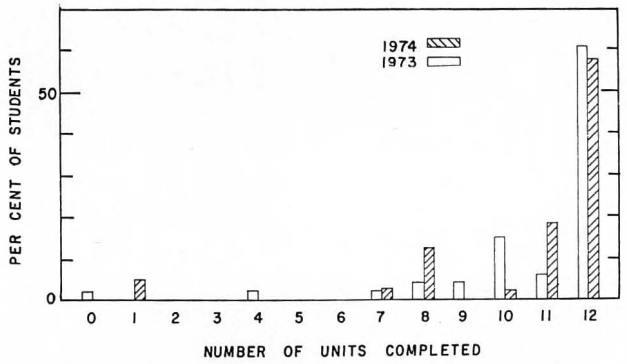

FIGURE 6. Frequency Chart for the Number of Units Completed.

compared to a 29 percent drop rate for a senior biological sciences elective course and a 20 percent drop rate for the required dynamics course offered in the sophomore year. [4] Both the latter courses are taught using self-paced methods. For the dynamics course, students also have the option of taking the course by the lecture format.

For the process dynamics and control course, the final examination is a comprehensive examination covering a sampling of all objectives. The score counts a little more than one-third of the final grade. The raw score distributions for the PSI course and the lecture course are compared in Figure 5. Nearly the same final examination was given for both courses. However, the examinations for the PSI courses covered somewhat more material and were closed book examinations. The examination for the lecture course was an open book examination. These data show that students who have studied by the PSI method do just as well if not better on written examinations as do students who have studied by the lecture method. In the range of raw scores between 30 and 75, the students who studied by the PSI method had generally higher scores than the students who studied by the lecture method. In the higher range and the lower range of raw scores, there does not seem to be much difference between the two groups.

In Figure 6, frequency data for the number of units completed by the end of the course are shown. Most students complete eleven or twelve units in the time allotted for the course. Comparing the data for 1973 (no late penalty) and 1974 (late penalty) shows again that the penalty for passing a unit late has no significant effect.

Correlations of final examination score with number of units completed presented in Figure 7 show that lower examination scores are typically associated with a smaller number of units completed though there is considerable scatter. The examination grades range downward from the perfect correlation line passing through the origin and a raw score of 100 for a student completing all twelve units. The data presented in Figure 8 show that no student who completed all units earned a "C" and that no student who did not complete all units earned an "A".

QUESTIONNAIRE RESULTS

AN OPINION questionnaire was employed during 1973 and 1974 to obtain student ideas about the course. Students generally feel that the objectives are clear and related to other courses and to professional practice. They are favorably disposed toward the textbook, the quizzes, and the

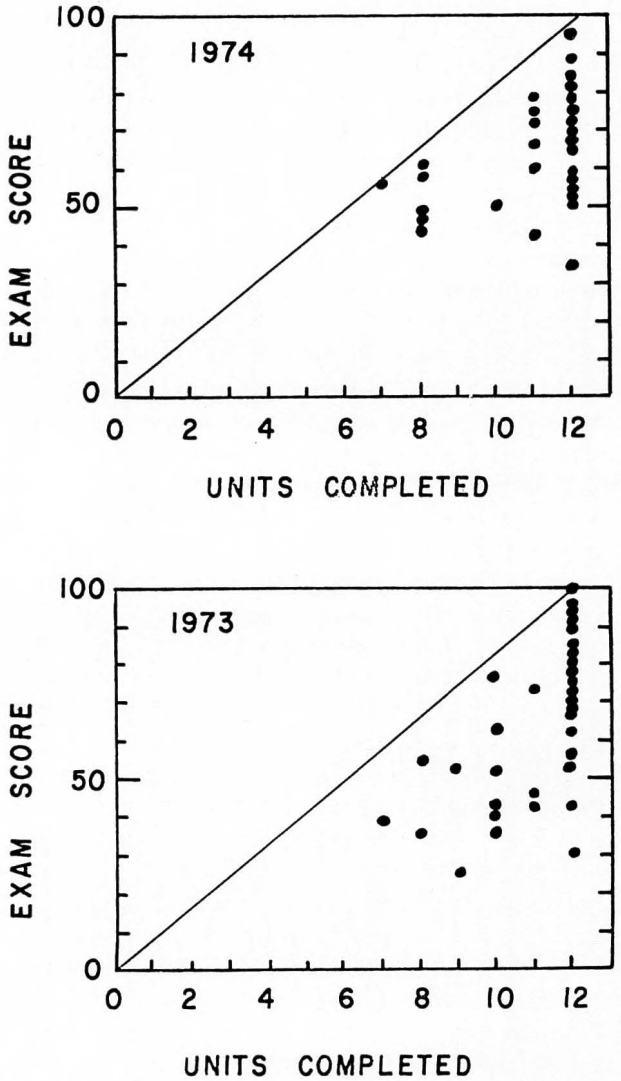

FIGURE 7. Examination Score Correlations.

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fermentation and enzyme engineering, and food processing.

- PROCESSES AND INDUSTRY (T. W. Fraser Russell, U. of Delaware) plans workshops on the economic structure of the chemical industry, process economics and industrial chemistry.
- CHEMICAL REACTIONS (Alexis T. Bell, U. of California, Berkeley) will cover instruction in chemical kinetics, catalysis and subjects related to reactor design and dynamics.
- APPLIED CHEMISTRY (Donald R. Woods, McMaster U.) is considering courses in electro-chemical engineering, metals processing, surface and colloid chemistry, and solid fluid separations.
- TEACHING METHODS (Ernest J. Henley, U. of Houston) will take up motivational techniques and alternatives to the lecture, as well as courses and curricula for non-chemical engineers and a modular course on safety and reliability analysis.
- ADMINISTRATIVE (John W. Prados, U. of Tennessee) tentatively will include sessions on evaluating faculty workload and performance, as well as faculty recruitment. Other sessions deal with the social and political aspects of engineering decision making, and one or more special topics.

The detailed content of the workshops is still taking form.

Financial support for the Summer School is being donated by a number of industrial companies. At the moment there are 15 participating companies, listed in Table 1. It is anticipated that the number of participating companies will soon reach 20 or more, further reflecting the broad base of funding for the Summer School. The level of financial support is such that it will be possible to give a travel subsidy to attendees from the various universities around the country. Information concerning applications for attendance and available subsidy will be distributed to Chairmen of ChE Departments, probably in late 1976.

HUBBARD: Instruction By the PSI Method

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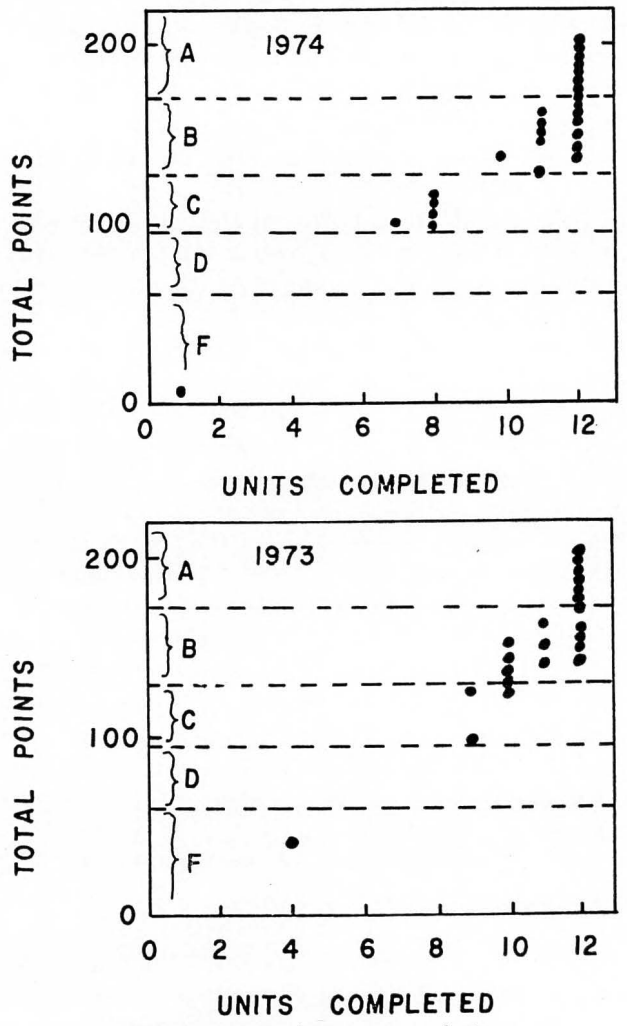

FIGURE 8. Total Score Correlations.

tutor system. They generally feel that supplementary notes could be written more clearly. Eighty-eight percent of the students returning the questionnaire feel that they learn more studying by the PSI method. Fifty-five percent of the students say that they prefer the PSI method to the lecture method. This is a somewhat lower preference than is usually seen for a PSI course. An overwhelming majority of students returning questionnaires usually say they prefer the PSI method. The lower positive response for the process dynamics and control course may be due to its being a required course. When there is a choice of format as in the required dynamics course mentioned above, thirty-three percent of the students usually choose the self-paced method. For the process dynamics and control course, students who prefer a lecture format do not drop out, because there is no choice. If there were a choice, those students would drop out and would not have the opportunity to fill out a questionnaire. The questionnaire data from elective courses may be biased in favor of PSI. □

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