

MASS TRANSFER OPERATIONS

WILLIAM L. CONGER
University of Kentucky
Lexington, Kentucky

It has always bothered me that my lectures do not seem to reach all of the students in my classes. The students, who we say are very intelligent, are often bored because we move too slowly. The students who we say are dull, are often so far behind that they have no hope of passing the course. Those students in the middle get the most benefit. I have often thought that there should be some way of challenging those "intelligent" students, keeping their interest, and motivating them to do more, while still handling the problems of the middle of the class and saving those of the "dull" group that were worth saving. I have tried various methods such as extra assignments, reports, etc. with very limited success.

A POSSIBLE SOLUTION

I was assigned by my dean as a young faculty delegate to the national meeting of the ASEE in June of 1970. This was a very profitable meeting for me, as I was exposed to a number of teaching techniques of which I had not known before. One of these the **Self-Paced Course** or as Keller^{1,2} calls it, the **Personalized System of Instruction (PSI)**, appeared that it might answer some of my criticisms on the lecture system.

Dr. F. S. Keller has developed the PSI method in order to obtain the most of every student's potential. In its unmodified form it includes the following features:

- (1) **Go at your own pace.** The student moves through the course at a speed commensurate with his ability and other demands upon his time.
- (2) **A unit-perfection requirement for advancement.** The student is allowed to proceed to new material only after demonstrating that he has a mastery over all preceding material.
- (3) **The use of lectures and demonstrations as motivation devices.** The student is allowed to attend special lectures only after achieving a specified level in the course.
- (4) **Stress upon the written word for communication between student and teacher.**
- (5) **The use of proctors.** The student is assigned to a proctor who tests, scores, and tutors on an immediate one to one basis.

In my case I had to modify Keller's ideal somewhat to eliminate (5), as I did not have the personnel nor the funds to provide a sufficient number of proctors to run the course exactly as Keller suggests. I decided that elimination of (5) was possible, because Chemical Engineering classes at the University of Kentucky generally contain under thirty persons (Keller's classes were in excess of one hundred students) and, therefore, I could assume those tasks assigned to the proctors in the system.

Of the remaining four points, (1) and (2) interested me the most. The system would accommodate the quick and the slow student (often confused with intelligence and dullness) and in addition would have equal reward for everyone for completing the same amount of material.

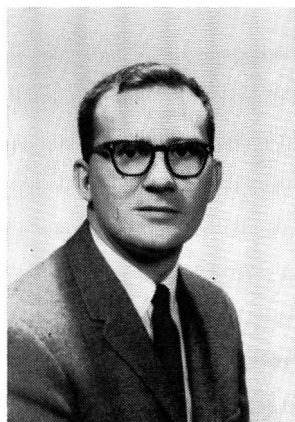
I decided to test the system as Dr. Billy Koen³ (University of Texas, Mechanical Engineering) and Dr. G. David Shelling⁴ (University of Rhode Island, Chemical Engineering) did with material given me by Dr. Koen and by Dr. Clyde H. Sprague of the Department of Mechanical Engineering, Kansas State University as a model, I developed a self-paced course in mass transfer based on the text **Mass Transfer Operations**.⁵

DEVELOPING THE COURSE

The first step in building the course was to **determine exactly what material I wanted to cover in the course.** I decided to cover the first ten chapters in the book with the exception of chapter 7 "Humidification Operations." I then broke this material down into twenty five individual assignments or tasks. The student must complete a task satisfactorily before proceeding to the next one.

The second step was to **find and correlate other references on the same block material so that the student would have several authors to read if he had difficulty understanding his primary text.** This was then presented to the students in twenty five separate assignment sheets or blocks each

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William L. Conger is a graduate of the University of Louisville and the University of Pennsylvania (PhD '65). He has been teaching at the University of Kentucky since January 1967 and has developed an interest in teaching techniques. His research interests are in the biomedical area.

giving an objective for the block, a reading assignment in the text, additional readings in other references, and problems to do with answers.

The third step was writing supplemental material of my own design to further reinforce the text material. In this supplement I spelled out the rules of the course, noted sections of the reading material that were of particular importance, and amplified sections of the text. A portion of this supplemental material explaining the course to the students is given below:

We are about to enter into a new type of learning process for most of you. This method that we will be using in this class is called "Self Paced Instruction." The method was developed by a Education Psychologist by the name of Keller; the method is designed so that everyone in the course will learn the maximum amount.

I have taken the material in *Mass-Transfer Operations*, Treybal, R. E., 2nd edition, McGraw-Hill (1968) and have divided a portion of it into block tasks. You will be given these blocks one at a time. You must finish the block given you before getting the next one in the sequence. Anyone finishing all the blocks will receive an "A" in the course, all but one block, "B", all but 2 blocks a "C". Anyone completing less than all minus 2 will be given an incomplete in the course. An incomplete must be removed from my books by the third week of the next semester. The deal of A, B, or C will still apply. Any incomplete not removed from my books will be given an E.

Everyone can get an "A," then what is this incentive to study and what rules apply

Rule 1 You must complete each block by answering with near 100% accuracy a very short assessment quiz. Don't memorize the material—learn it, for each subsequent block will depend on the previous blocks. Also I

* Examples of the tasks, quizzes and supplementary material are available from the author.

reserve the right to ask you a question on any previous block in an assessment quiz. If you fail to get 100% on the quiz, I will ask you a question or two orally to see if you just didn't understand my question. If I determine that it was my question, and you really know the material, I will pass you to the next block. If you miss too many questions on the assessment quiz, I won't use the oral exam.

Rule 2 You may take the assessment quiz, as many times as you need to get 100%. A new quiz will be used each time.

Rule 3 You may not take more than 2 assessment quizzes on any one day, and at least one hour must elapse between starting quizzes.

Rule 4 Quizzes will be administered at noon and at normal class time on Monday, Wednesday, and Friday. Quizzes will be administered at noon and an hour of the students selection on Tuesday and Thursday. No quizzes will be given on Saturday, Sunday or Holidays. If there is a conflict on the normal M.W.F. schedule so that a student can't use the noon hour for quizzes, exception to the above rule will be made.

Rule 5 All assessment quizzes will be closed book.

Rule 6 The classroom and hour assigned to this class will be used for studying the material. You are to study outside class also, but I expect you to show up and use the time and space allotted.

Rule 7 Once you have finished all blocks satisfactorily you receive your "A" and you are finished with the course. I don't care if you finish in 6 weeks as long as you finish. Once finished you don't have to attend class anymore.

What is all of this worth to you? Well, if you finish the course, you get an "A," and you should have an excellent grasp of the material. Studies have shown that students using this method learn more—more quickly and retain the material better.

This method does this for you also: no longer are you competing with your fellow student—you are competing with the material only.

Now some study hints:

1. When you get a new block, look over the instruction sheets I give you thoroughly. Then skim the required reading just looking at the topics to be covered.
2. Next, go back over the reading and try to pick out the important points. Now put the material down and do something else for some time.
3. Go back to the reading and go over it once again, hitting the high spots you have picked out.
4. Now go to the problems, if any, and work with them until you can get the correct answers.
5. Study together—teach each other. The best way to learn something is to try to explain it to someone else. If you can make another person understand a particular principle, then you will know it.
6. Now we get down to my function besides organizing this, writing the supplemental material, etc. If you go through step 5 and still have questions, your next recourse is me. Ask me the questions; make me answer them. I will be available at class time and at the times posted on my door. Your job is to learn the material—my job is to clarify the material if you have trouble.

The students were overwhelmingly in favor of the PSI method. They liked the continuous testing and found it easy to pace themselves.

The fourth and last step was developing a series of quizzes to test the students capabilities with the material. The quizzes should not be exactly the same so I developed up to eight separate ones for some blocks down to only two for one block. The average was about four quizzes per block which covered the material from previous blocks to test retention. The quizzes were generally short averaging 15 to 20 minutes to complete. Several were longer, however, taking up to an hour to complete.

RESPONSE TO THE COURSE

We have seen the reasons why I chose to teach a course this way, and how I applied Keller's theories to the course materials. Now, what were the results of my efforts. The assessment quiz for the final block was a course evaluation modeled somewhat after Koen's³ but modified to meet my personal situation. The results of several selected questions are given below. I was happy to find basically the same responses as Dr. Koen found. I had 21 students taking the course. All but one completed the course in the normal semester; that one has completed all but two blocks at this writing and should complete these shortly.

Questions	No. of responses			
	Def. Yes	Yes	Def. No	No
The quiz material was designed to make the block material more meaningful to me.	13	7	0	0
This course caused me to work beyond the normal effort I put into a course	9	8	2	1
I felt that there should be some lecture associated with the course	0	7	10	3
I was able to get help from other students in the class when I had a question	4	13	3	0
I understood what was expected of me in the course.	12	8	0	0
I missed the usual grading system and tests.	0	0	5	15
I would like to see more classes taught this way	17	3	0	0
I was frustrated to have to pace myself.	0	2	10	8

The supplemental reading material was helpful.	3	10	6	1
The material I covered has caused me to think.	16	4	0	0
I think I learned a substantial fraction of the material in the book	17	3	0	0
The quizzes were general enough to cause me to study all the material.	10	8	2	0
I could find out what to study from the people who had already been through a block.	0	11	9	0
I did not study all the material in every block because I could find what was going to be on the quiz.	0	1	15	4
I found it difficult to pace myself.	1	4	8	7
I was hurried to complete the course.	1	1	12	6
Is this approach worth continuing in this class in the future?	18	2	0	0
Should there be regular lectures, say once a week on Friday, to cover related material to the course?	3	8	8	1

Questions	No. of Responses
This course was of the courses I have taken.	
a) the best	8
b) one of the best	10
c) above average quality	2
d) average or lower	0
Among the courses I have had this course was for stimulating me to new ideas.	
a) the best	5
b) one of the best	12
c) above average	3
d) average or lower	0
I consider this self-paced instruction to be:	
a) better than the lecture method	19
b) as good as the lecture method	1
c) inferior to the lecture method	0
d) a detriment to the student learning.	0

As we can see the students were overwhelmingly in favor of the PSI method, and the results that it gave. They liked the continuous testing even though they spent several more hours in testing than they would normally. The self-paced feature did not frustrate their efforts (I had two students drop the course: one because of personal problems, another because he did not pace himself correctly), and most found it easy to pace themselves. In general they did not miss the lecture

but indicated that they would like a few throughout the semester. Most important to me, they knew what was expected of them, and showed a strong desire to have this method continued.

It appears from this data and in independent course evaluation conducted by the Student Council in the College of Engineering that the students did like the course and how the material was presented. The students think that they have a better grasp of more material than previous classes, but is this true? A comparison of grade distribution with previous classes is not a fair measure, since I promised an A to everyone who met all the course requirements. How then can I compare the level of understanding of these students with previous classes?

The comparison I needed was made unwillingly by the students themselves. The present seniors had taken the same course the previous year under one of our faculty who is consistently rated by the students as one of the best teachers in our department. I found many cases where the seniors had gone to my juniors to have a principle or problem explained to them. The seniors have categorically stated that my class has a far better understanding of the material covered than they have. I might note here that we covered more material than previous years. I therefore feel that the course accomplished its objective of conveying a certain level of understanding of an engineering subject to all the students in a class (fast, average, or slow learners).

ANALYSIS OF RESPONSES

I have asked myself, was the improvement I saw a result of the course structure or a result of just changing format? If I had used any other format modifying the normal lecture, would I get similar results? Is this a Hawthorne effect where any change produces an increase in productivity? I don't think so. I believe that this method can answer many of the problems that we have in conveying information to our students. I do not, however, believe that this is the only method that should be employed. I think that a variety of teaching methods will help the students generate the motivation that is so often missing.

EFFECT ON INSTRUCTOR

One final note on how all this affects the instructor of a course. The amount of work necessary in order to prepare a course like this far

surpasses what is normally necessary. But once organized, the course can be used again and again with minor modifications. The overall economy of time would then approach conventional courses.

The instructor can feel somewhat left out at times in using this method. Lecturing makes many of us feel secure; the absence of the regular lecture eliminates this secure feeling. The instructor does have more personal contact with each individual however, and this allows us to bring out the student's capabilities.

The method lends more flexibility to the instructor. I had a student who had to serve in the armed forces for three months during the summer. Unfortunately for him his tour of duty lasted into the first of our semester, and the University would not let him register. If he had been allowed into normal courses, he would have been far behind and would not have derived the full benefit of the course. In addition the course in question here is a prerequisite for a number of courses, and he would have had at least one full year added to the time for graduation had he not had to serve. I am able to give this student this course (because of its structure) so that he will be able to take the following courses. He will register for independent study next semester and get credit for his work. This will allow this young man to graduate as he had planned.

CONCLUSIONS

I have found the PSI method developed by Keller a powerful tool in teaching Chemical Engineering subject material, and I intend to continue using the method in the future. Because of the reinforcement technique used in the method, there is every reason to believe the students' retention of the material will be excellent. Students agreed that they generally worked harder and enjoyed this course more than most.

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