

AN EXPERIMENTAL CLASS IN STATICS USING THE PERSONALIZED SYSTEM OF INSTRUCTION

By

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INTRODUCTION

Courses in mechanics have, through the years, proven to be difficult to many engineering and architecture students. Even after several changes in textbooks, professors, teaching styles, and examination systems, the failure rate in mechanics remains high. In E.S. 11; Statics of Rigid Bodies, there are semesters when only about half the students enrolled receive passing grades.

Students in the University of the Philippines who are able to reach as far as E.S. 11 in their studies have undergone a number of screening processes. Many of the less able have been weeded out by the U.P. College Admissions Test as well as by the courses in mathematics and physics they have to pass before becoming eligible to take E.S. 11. Perhaps, the quality of students who enter the courses in mechanics is not really as bad as their performance indicates. This may be more a case of under-achievement than incompetence.

From conversations this writer made with engineering students, it appears that students spend less time than they should in studying their lessons. To gain thorough understanding of the subject, the rule of thumb for most college courses is two hours of out-of-classroom work by the student for each unit of lecture credit registered in. Many students confess to devoting less than an hour of studying for each hour of lecture in mechanics that they attend. While these conversations do not constitute a basis for concluding the study habits of students in mechanics, they, nevertheless, indicate that inadequacy of effort may be one of the principal reasons for the high failure rate. This writer believes that if our students can be sufficiently motivated to do the work they are supposed to do, their performance in mechanics will significantly improve.

The Personalized System of Instruction or the Keller Plan has a reputation for being highly effective in motivating students to study. This writer decided to try this system of instruction in a Statics class in U.P. during the first semester of academic year 1979-1980. The Keller Plan has been

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used previously for teaching Statics in a number of schools abroad like the University of Texas in Austin, Michigan State University, and the Instituto Tecnológico y de Estudios Superiores de Monterrey in Mexico.

This is a report on how the experimental class in Statics in the University of the Philippines was conducted and the outcome of the experiment. This project was sponsored by the National Engineering Center.

THE PERSONALIZED SYSTEM OF INSTRUCTION

The Personalized System of Instruction (PSI) was developed by a group of American and Brazilian psychologists, composed of Fred S. Keller, J. Gilmore Sherman, Rodolfo Azzi, and Carolina M. Borri, who used it for teaching an introductory course in psychology at the University of Brasilia in 1964. PSI was first used for teaching an engineering course in 1969 by Prof. Billy V. Koen of the University of Texas in Austin. Koen employed this instructional method for teaching an undergraduate course in nuclear reactor engineering.

Variations exist in the manner of implementing the PSI among users. The following features, however, are present in all PSI classes:

- “1. The go-at-your-own-pace feature, which permits a student to move through the course at a speed commensurate with his ability and other demands upon his time.
2. The unit-perfection-requirement for advance, which lets the student go ahead to new materials only after demonstrating mastery of that which preceded.
3. The stress upon the written word in teacher-student communication.
4. The use of proctors, which permits repeated testing, immediate scoring, almost unavoidable tutoring, and a marked enhancement of the personal-social aspect of the educational process.”**

The format used for implementing the PSI class in Statics is described in the following announcement. This announcement appeared in a number of bulletin boards of the College of Engineering prior to and during the registration period.

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ANNOUNCEMENT

ES 11 QRI & QR2
(PSI Sections)

2:00-4:00 PM, MWF, Eng'g. Theater

The classes in ES 11 QR1 and QR2 during the first semester of academic year 1979-1980 will be conducted using the Personalized

** Keller, Fred S., “Goodbye, Teacher . . .”, *Journal of Applied Behavioral Analysis*, Vol. 1, No. 1 1968, pp. 78-89.

System of Instruction (PSI). This is a method of instruction which permits each student to move through the course at the pace he chooses.

Under PSI, a student who is willing to work, devote time and effort to studying, can practically assure himself that he will pass the course. This is because PSI allows each student to take make-up examinations in all tests that he fails. A failing grade is not recorded. In addition, every student is permitted to take as many make-up examinations he needs until he passes each test. Unbelievable?

The details of the system are listed below:

1. The course is divided into 17 units. Each unit consists of a set of topics which are all discussed in the text. Units 1 to 15 are required units; units 16 and 17 are optional.
2. A student must demonstrate *mastery* of each unit before being allowed to proceed to the next unit. Mastery of a unit is demonstrated through a readiness test which a student may take during any class period he chooses. (You read it right. You, the student, choose the day when you take a test!) No penalty is incurred for failing a readiness test. For each unit, you will be permitted to take as many readiness tests as necessary until you demonstrate *mastery* of that unit.
3. Each readiness test can be completed in approximately 30 minutes. However, so that you will never be pressed for time during my examination, you will be permitted to spend as much as one and one-half hours for every test. This is the reason why the length of the class period is two hours: as much as 90 minutes for test-taking and the remainder of the period for correcting the papers. Your papers will be corrected *immediately* after you submit your solutions.
4. Any student who completes 15 units by the last day of classes (October 5, 1979) gets a grade of 2.0. A student who completes all 17 units during the semester gets a grade of 1.0. Any student who did not drop the course and failed to complete 15 units by the last day of classes gets a grade of 5.0.
5. Each student will be furnished a copy of the textbook and a set of study guides. The study guide for each unit will tell you what the instructor expects you to learn and what you will be examined on in that unit. It will also contain a discussion section which explains further the materials in the text. The study guide for each unit includes the complete solution to some of the problems in the text.

6. No lectures will be given but several tutors will be available during every class period. You may consult the tutors as well as your professor and they will personally provide assistance to each individual student.
7. The room that is assigned to the class will be used by the students as a place for studying, tutoring, and taking the tests. If you prefer to study the assignments elsewhere and you feel you do not need the services of the tutors, then you come to class only when you want to take a readiness test. In other words, class attendance is optional.
8. The time when you finish the course depends on you. A student who takes and passes one readiness test during every class session will finish the course on July 25, 1979 and receive a grade of 1.0.
9. Other details about the mechanics of implementing this course will be given on the first day of class. Be sure to arrive on time on the first day of class (June 13).

A word of caution: This system of instruction is NOT RECOMMENDED for students who have a tendency to procrastinate and who are unable to exercise self-discipline. If you have questions about PSI, feel free to consult me in the Graduate Division, Room 223.

EDGARDO S. PACHECO
Professor, PSI Sections

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THE PSI CLASS IN STATICS

A total of 52 students registered in the PSI class in Statics. All students in the class chose the PSI section voluntarily from among the 12 sections in Statics that were opened. The class consisted of 21 students from the College of Engineering, 17 from the College of Architecture and 14 pre-engineering students from the College of Arts and Sciences.

The Engineering Theater served as the classroom for the course. The theater was roughly divided into three areas: one for testing, one for tutoring, and a third area where students can study individually or in groups.

During each class session, five tutors provided tutoring services to the students. The tutors also graded the readiness tests. This writer, as class instructor, was present in all class sessions, supervising the work of the tutors and serving as arbiter when differences of opinion arise between students and tutors.

The regular tutors for this class were 14 graduate students majoring in Engineering Education and enrolled in Education 381; Workshop in College Teaching. Two hours per week of tutoring in the PSI class constituted part of the laboratory activities of each student in Education 381. Thus each of the tutors had to attend only one class session of Statics a week.

Two instructors in the Department of Engineering Sciences, Ms. Armi Exmundo and Mr. Angel Caringal, were interested in observing how a PSI class is conducted and volunteered to assist in running the class. They attended most of the class sessions and did a fair amount of tutoring and grading of tests.

It must be pointed out that the number of tutors required for a PSI class of 52 students is not as large as was used here. All 14 students in Education 381 served as tutors simply because it was the intent of their course to expose them to the PSI and other methods of instruction. The desirable tutor-student ratio will be discussed in a later section of this report.

In order to assure that readiness tests for any unit are available to all students qualified to take them, it is essential that many of these tests as well as the study guides for at least the first few units be made and printed before the start of the semester. For the Statics class, copies of readiness tests and study guides for the first seven units were ready at the start of the semester. The draft of most of the remaining study guides and readiness tests were already completed by the time classes for the semester began.

Because students will generally be taking the readiness test for each particular unit on different days, it was necessary that several test forms be prepared for each unit. The different test forms for a unit were designed to be of approximately equal difficulty.

At the start of the semester, it was thought that the number of test forms needed for each unit will not exceed eight. As the semester progressed, however, it was necessary to make additional test forms in certain units in order to reduce the number of times the same test form is used during the semester. The construction of many test forms minimized the possibility that the slow moving students were answering test questions on which they had already been briefed by their more advanced classmates.

So that only one test form for each unit will be used on any class day, the students were informed that the latest time they can start a readiness test is 2:30 p.m. Those who took the test earlier were instructed not to leave the room earlier than 2:30 p.m. This assured that students who finished the test early were not able to transmit information about the test to those who started late.

To facilitate the grading of readiness tests, each tutor was provided a manual, essentially a solutions manual for the questions in the readiness

tests together with a few instructions on how the tutors should react to certain anticipated student answers. For security reasons, the tutors were not allowed to bring the manuals home with them. They were distributed to the tutors at the start of the class period and collected at the end of the period. During non-class hours, the tutors were given access to the manuals only in the office of this writer.

The tutors were instructed to mark the student papers "Pass" if all questions were answered correctly and "Recycle" if there were conceptual errors in the solutions. The students were immediately given the study guide for the next unit after passing the test for the preceding unit. A mark of "Recycle" meant that the student had to restudy the materials for the unit and present himself for retesting in that unit on any other day he chooses. Whether a student passed or was recycled, he was permitted to take only one test per class session.

The students were given the opportunity to review and correct their work if, in the tutor's judgment, the errors they made were trivial in nature, e.g., errors in arithmetic, forgetting to place the units, miscopying some data, etc. In all cases, the students were required to turn in to the instructor the test forms, the solutions, and all scratch paper used.

During the first three weeks of classes, the tutors were given briefings on what their responsibilities were. The briefing was conducted after each class session.

CLASS PERFORMANCE DATA

The first day of class was devoted to a discussion of what the PSI was all about. Because of the novelty of the instructional method, the students asked many questions and had to be reassured that there was indeed no limit to the number of opportunities that will be given to them to pass a unit. In order that the students will get started early in the course, this writer strongly suggested that all of them take their first readiness test on the next class meeting (June 15, 1979).

Fifty of them did show up to take the readiness test for Unit 1 on June 15. The class attendance for the entire semester is shown in Table 1. This table does not include, among the students present, those who came to class but did not take a readiness test. There were indeed a few students who were present in the theater studying or discussing with fellow students and tutors but decided against taking a test on that day. Most of the students who came to class, however, took the tests.

TABLE 1
ATTENDANCE RECORD

Class day No.	1	2	3	4	5	6	7	8	9	10	11	12
Number present	*	50	35	47	47	39	41	46	48	49	38	35

* First day of class; no attendance record taken

TABLE 2
RATE OF PROGRESS OF PSI CLASS

CLASS Day No	NUMBER OF UNITS COMPLETED																	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
3	12	31	9															
6	1	11	9	19	9	3												
9		2		12	17	14	7											
12		1		5	8	14	14	6	4									
15		1		1	5	13	7	6	13	5	1							
18		1		1	2	13	5	4	11	5	4	5		1				
21		1				6	7	4	9	5	6	5	6	2	1			
24		1				5	4	4	9	2	5	5	7	4	2	3	1	
27		1				5	2	2	7	6	2	4	7	3	5	2	5	1
30		1				4	1	3	6	1	6	3	7	5	2	3	6	4
33		1				3	1		7	1	3	4	5	6	4	2	6	9
36		1				3	1		4	3		7	5	1	8	2	6	11
39		1				3	1		1	1	1	4	7	3	3	4	7	16
42		1				3	1		1		2	3	5	5	2	6	5	18
45		1				3	1		1		1	1	1	7	3	4	9	20
48		1				3	1		1		1	1			2	12	4	28

Class Day No.	13	14	15	16	17	18	19	20	21	22	23	24
Number Present	38	37	44	35	32	36	36	35	32	26	36	38

Class Day No.	25	26	27	28	29	30	31	32	33	34	35	36
Number Present	36	33	27	**	33	33	33	25	26	20	24	24

** Classes suspended due to bad weather

Class Day No.	37	38	39	40	41	42	43	44	45	46	47	48
Number Present	26	18	11	15	16	13	22	23	21	18	17	13

Attendance was quite heavy during the first few days of class. Afterwards, it stabilized to about 70 percent enrolment up to class meeting No. 31. The attendance declined considerably after meeting No. 31 for the following reasons:

- 1) Five students already passed 17 units and were therefore through with the course.
- 2) Five students dropped the subject because they were lagging far behind in their lessons.
- 3) One student who completed 15 units was contented to stop right there.

Table 1 can serve as a guide for future PSI classes in determining the suitable number of tutors in a class. This writer observed that a tutor had no difficulty assisting students who consulted him prior to taking tests, and subsequently, grading the test papers of seven students. Tutors with excellent knowledge of the subject matter of the course were able to take care of nine students during each class period with little waiting time problems. This experience indicates that a class of 52 students can get along comfortably with only five tutors. This is in agreement with the experiences of previous users of PSI who found a tutor-student ratio of 1:10 to be suitable.

In order to keep track of the progress of each student, a Student Progress Chart was used. Shown in the next page is the progress chart of one of the students in the PSI class. Each readiness test is identified by a unit number and a letter. Thus, if there are five test forms in Unit 1, the tests would be labelled 1A, 1B, 1C, 1D and 1E.

The letter entry in the progress chart identifies the test form given to the student for the unit indicated in the left column and on the class day indicated in the bottom row. An uncircled letter entry means that the student took the test form corresponding to that letter but did not pass it. When a letter entry is encircled, it means the student passed the readiness test.

Information on the progress of the PSI class itself is supplied by Table 2.

The entries in Table 2 are the number of students who completed the number of units indicated in the top row as of the class day shown in the left column. For example, as of the 21st day of class, one student completed only one unit, 6 students completed 5 units, 7 students completed 6 units, 4 students completed 7 units, etc.

In order to obtain a passing grade in the course and assuming linear progress, a student must pass one readiness test approximately every three class sessions. The dark, jagged lines roughly represent this linear progress. The figures to the left of the jagged lines represent the number of students who were progressing at a rate slower than the linear rate which assures passing of the course.

It can be seen from this table that approximately one-fourth to one-third of the class was progressing at a rate slower than what can be considered a safe pace. An examination of the attendance record of the slow students reveals that only about six of them can be classed as procrastinators. The others were progressing slowly simply because they were recycling (i.e., retaking tests) very often. The units where the students encountered the most difficulties have been identified and efforts are being exerted to improve the study guides for these units.

It will be noted from Table 2 that after two-thirds of the semester (meeting No. 33), 9 students already completed the course with grades of 1.0 and 8 more were already assured of getting at least 2.0 in the course.

As of the last day of class, there were two students who completed only 14 units. They should have been given grades of 5.0 outright since it was announced at the beginning of the semester that students who fail to complete 15 units by the last day of class will be given failing grades. It was decided, however, to give these two students another chance by permitting them to take the final examination given to students of the other sections in E.S. 11. The other sections used 64 percent as the passing grade for the course. These students who completed only 14 units were told that they will be given a grade of 3.0 if they obtained the passing grade in the final examination. Otherwise, the grade that will be given to them is 5.0. One of them got 69 percent in the final examination and the other got only 42 percent. Table 3 below shows the distribution of final grades in the PSI class.

TABLE 3
FINAL GRADE DISTRIBUTION

Final Grade	1.0	2.0	3.0	5.0	DRP.
No. of Students	26	16	1	3	6

To ascertain which units were giving the students the most difficulties, a count was made of the number of "Passes" and "Recycles" for each unit. This is shown in Table 4. The entries under the columns Pass and Recycle are the number of papers marked Pass or Recycle, respectively, in the readiness tests indicated by the leftmost column. Thus, in the readiness test for Unit 8, there were 47 papers marked Pass, and 31 papers marked Recycle. This means that, on the average, only 60.3 percent of the students who take a readiness test in Unit 8 pass each time a test in this unit is given. This makes Unit 8 the 11th most difficult unit in the course. This table gives an indication of the units where improvement of the learning materials or re-evaluation of the test questions may be necessary.

TABLE 4
ORDER OF DIFFICULTY OF UNIT TESTS

<i>Unit No.</i>	<i>Pass</i>	<i>Recycle</i>	<i>% Passing</i>	<i>Order of Difficulty</i>
1	52	32	61.9	13
2	51	43	54.2	8
3	51	5	91.1	17
4	51	44	53.6	7
5	51	48	51.5	6
6	51	83	38.1	2
7	47	48	49.5	5
8	47	31	60.3	11
9	46	54	46.0	4
10	46	29	61.3	12
11	45	26	63.4	15
12	44	37	54.3	9
13	44	53	45.4	3
14	43	25	63.2	14
15	42	28	60.0	10
16	30	5	85.7	16
17	26	62	29.5	1

STUDENT ASSESSMENT OF PSI

During mid-semester, the students were asked to fill out evaluation sheets to obtain their opinion on the learning materials used and on the effectiveness of the PSI. Unlike lecture classes where student evaluation is usually carried out near the end of the semester, PSI evaluation must be done around mid-semester. This is because some students will be out of the class beyond this date either because they have already completed the course or have dropped out to due slow progress. In fact, at the time the PSI students were asked to evaluate the course, there were three students who have already stopped attending the class.

The students filled out the evaluation sheets on the 24th, 25th and 26th days of class. It was necessary to carry out the evaluation over several days since not all students come during each class session. There were 42 respondents out of 52 students enrolled in the class.

In the first ten items of the evaluation form, the students were asked to compare the PSI class in E.S. 11 with an equivalent lecture class (e.g., E.S. 21, Mathematics, Physics, Chemistry) by rating the statements in each item using the following comparison scale:

—:—————:—————:—————:—————:—
1 2 3 4 5
PSI is inferior PSI is equivalent PSI is superior to lecture method to lecture method to lecture method

The following are the frequencies of the responses for the first ten items:

	<i>Rating:</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
	<i>Frequency of Responses</i>					
1. Development of genuine interest in subject				6	25	11
2. Understanding of fundamental concepts and principles.			1	6	19	16
3. Learning of material thoroughly enough for long retention.			1	8	22	10
4. Efficient use of student's time.			2	6	13	21
5. Enjoyment of learning experience			1	4	17	20
6. Accurate measurement of material learned.	1	2		5	20	14
7. Development of desire to investigate subject beyond course requirement.			1	20	16	5
8. Effectiveness in motivating students to study.				2	18	22
9. Integration of subject matter covered by the course.			1	9	16	14
10. Preparation for professional life after graduation				17	14	11

There were five other items in the evaluation form and the frequencies of the responses are tabulated in the next page:

	<i>Frequency</i>
1. I consider the textbook used in the course to be	
a) poor	0
b) below average	0
c) average	15
d) above average	22
e) excellent	5

2. I consider the study guides used in this course to be	
a) poor	0
b) below average	1
c) average	9
d) above average	17
e) excellent	15
3. For developing a clear understanding of principles and applications, I found the study guides to be	
a) completely unnecessary	0
b) of minimal usefulness	0
c) occasionally useful	6
d) very useful	26
e) extremely useful	10
4. Compared with the amount of time I usually put in a 3-unit course my effort in this course is	
a) well below average	0
b) below average	1
c) average	15
d) above average	19
e) well above average	7
5. Given another opportunity to choose between a PSI and a lecture section of a subject, I will	
a) definitely choose the lecture section	0
b) choose the lecture section	0
c) take either one (no preference)	2
d) choose the PSI Section	13
e) definitely choose the PSI Section	27

The results of this survey confirm the findings of other teachers who used PSI in their classes, namely, that students are highly motivated, that they enjoy learning under this system, and that they feel they are learning the materials well. It is noteworthy that 40 out of the 42 respondents will choose a PSI section over a lecture section given another opportunity to make the choice.

FOLLOW-UP ACTIVITIES

The information gathered in this experimental PSI class in Statics points to certain areas where improvement in the course materials and changes in the manner of conducting the class may be made.

Table 4 shows clearly the units where the students encountered the most difficulties. A review is now being made of the solutions of the students in the tests for these units. The more common errors committed by the students are being identified and changes will be made in the study guides

either to clarify or to amplify those points which students find unclear. The readiness tests themselves are being reexamined and those questions that were misinterpreted by many students will be recorded.

Some of the tutors commented that each test covers only a small amount of course material. It, therefore, appears that no assessment has been made of the students ability to integrate the concepts, principles and techniques learned in the various units. Actually, the nature of the course in Statics is such that knowledge of previous lessons is usually necessary for an understanding of succeeding lessons. A certain amount of integration of materials is, therefore, already built in the course.

Nevertheless, there is merit in taking more deliberate steps in assessing how well the students learned the course as a whole. In the next PSI class, one of the required units will be one which reviews the core content of the course. To prepare for the readiness test for this unit, the student must review friction, trusses, frames, force systems in space, and moment of inertia of areas and thin plates. The questions in the readiness tests for this review unit will be designed in such a way that a well-prepared student can finish the test in about an hour. The students will be given a maximum of two hours to finish the test.

The offering of other subjects using PSI is under consideration. The preparation of the learning materials for a PSI class in Mechanics of Deformable Bodies is expected to begin in January, 1980.

CONCLUSION

This experiment on the use of the PSI in a class in Statics was carried out in response to the problem of high failure rates in courses in mechanics. A study of the grade of U.P. students in Statics during the past three academic years (1976-1977 to 1978-1979) shows that only 58 percent of all students enrolled received passing grades. The rest either dropped the course, received failing grades, or got grades of Incomplete. In sharp contrast to this, 83 percent of the students in the PSI class passed the course. From the point of view of student grades, the PSI experiment is an unqualified success.

The more important question, however, is whether the students in the PSI class learned more than the students in the traditional lecture classes. This question cannot be answered categorically in this paper since there was really no control group in this experiment. The examinations that students in the PSI section took were different from those taken by students in the lecture section. There was no common yardstick used in assessing how much was learned by the two groups of students.

An observer of the PSI class, however, will not fail to see the enthusiasm of the students towards their studies. They studied their lessons regularly instead of cramming once a month or so. They consulted their teacher and their tutors much more frequently than students in the lecture sections

usually do. Their jubilation each time they pass a readiness test was very much in evidence — they feel rewarded and are encouraged to keep up their work. At the same time, they took recycling in stride knowing that they have other chances of demonstrating their mastery of the same lesson. There was no tension when students took tests and no hostility towards teacher or tutor was in evidence when students failed to pass a test.

The requirement of mastery of each unit assured that there were no gaps in the student's knowledge of the core materials of the course. The students worked harder to achieve the required mastery. This writer and the tutors observed that the students were really putting in a lot of effort into the course. What is more, they seemed to be thoroughly enjoying what they were doing.

The conditions that promote learning were provided by this method of instruction and this writer witnessed the students reacting positively to the incentives offered by PSI. When the students were asked to evaluate the PSI class, they gave it exceedingly high marks. There are few educational innovations than can elicit as favorable a response from students as was generated by the PSI.

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Rosula R. San Jose	University of Santo Tomas
Carlos S. Satiembre	Southwestern University

They not only rendered invaluable tutoring services but also gave comments and suggestions which led towards more effective management of the class.

About the Author

Dr. Edgardo S. Pacheco obtained his BSME degree from U.P. in 1953, a MSE degree from the University of Michigan in 1958, and a Ph.D. degree from Northwestern University, Illinois in 1969.

He is presently a professor of Engineering Sciences at the U.P. College of Engineering. For many years, he has been teaching subjects in Mechanics, Applied Mathematics and Computer Programming of both undergraduate and graduate students.

He is currently a Consultant for Teaching Materials Development at the National Engineering Center.

His list of articles and books published include:

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